City of Stockton
Stormwater Quality Control Criteria Plan

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SECTION 1
BACKGROUND AND GOALS

Background

In 1972, the Federal Water Pollution Control Act (also referred to as the Clean Water Act (CWA)) was amended to provide that the discharge of pollutants to Waters of the United States from any point source be prohibited, unless the discharge is in compliance with a National Pollutant Discharge Elimination System (NPDES) permit. In 1987, further amendments to the CWA added Section 402(p), which established a framework for regulating municipal and industrial stormwater discharges under the NPDES program through a two-phase implementation plan. Phase 1 regulations, promulgated in 1990, require metropolitan areas with a population greater than one hundred thousand and specific categories of industrial facilities, to obtain an NPDES permit for stormwater discharges. Phase 2 regulations, promulgated in 1999, require designated communities or regions that operate municipal separate stormwater sewer systems (MS4s) and have populations less than one hundred thousand to obtain an NPDES permit for stormwater discharges. The City of Stockton (City) has a population greater than 100,000 but less than 250,000. The stormwater sewer system operated by the City, which services the City, the urbanized areas of the County of San Joaquin (County) that are enclosed within the City, and the urbanized areas which surround the City (collectively called the Stockton Urbanized Area), was designated as a Medium MS4 subject to Phase 1 stormwater regulations based on several criteria for designation including; proximity of the County's urbanized areas, their physical interconnections to the City's storm sewer system, and the locations of the County's discharges relative to the City's system.

In 2002, the City and the County received a Phase 1 municipal NPDES permit issued by the California Regional Water Quality Control Board, Central Valley Region (RWQCB) for stormwater discharges from the Stockton Urbanized Area. Under this permit, the City is required to develop, administer, implement, and enforce a Planning and Development Program to reduce pollutants in runoff from new development and redevelopment to the maximum extent practicable (MEP). The program emphasizes all aspects of pollution control including, but not limited to, public awareness and participation, source control, regulatory restrictions, water quality monitoring, and treatment control.

The program also requires the City to specify control for post-construction runoff from new development and redeveloped areas. This Plan, provided herein, provides development standards on these controls, including general site controls, source controls, and treatment controls. The types of new development and significant redevelopment that are required to implement the controls identified in this Plan include the following:

- home subdivisions with 10 or more housing units;
- commercial developments with impervious areas greater than 100,000 square feet;
- automotive repair shops with impervious areas greater than 5,000 square feet;
- restaurants;
- parking lots greater than 5,000 square feet or with 25 or more parking spaces;

- streets and roads with one acre or more of impervious area; and
- retail gasoline outlets with 5,000 or more square feet of impervious area.

“Source Control Measures” and “Treatment Control Measures”, as used in this Plan, refer to Best Management Practices (BMPs) and features incorporated in the design of a land development or redevelopment project that prevent and/or reduce pollutants in stormwater runoff from the project. Source Control Measures limit the exposure of materials and activities so that potential sources of pollutants are prevented from contacting stormwater runoff. Treatment Control Measures are reasonable, engineered systems that provide a reduction of pollutants in runoff to be consistent with the MEP standards imposed by the Federal Clean Water Act on the City.

The standards set forth in this Plan shall apply to all developments that receive an approved tentative map after the date of adoption of this Plan by the City Council and to developments that have an approved tentative map prior to the date of adoption of this Plan by the City Council, but have not obtained City Engineer’s approved improvement plans within two years of adoption of this Plan by the City Council.

In addition to the City permit requirements, owners/developers of some of the sites in the City may also be subject to the State of California’s general permit for stormwater discharge from industrial activities (Industrial General Permit) and general permit for stormwater from construction activities (Construction General Permit). The control measures provided in this Plan may assist the owner/developer in meeting the requirements of the State’s permit. The City’s stormwater management staff is available to provide assistance regarding State permit requirements.

Goals

This Plan has been prepared by the City of Stockton to accomplish the following goals:

- Assist new developments in reducing urban runoff pollution to the "maximum extent practicable”;
- Ensure the implementation of measures in this Manual is consistent with NPDES permit and other State requirements;
- Provide development standards for developers, design engineers, agency engineers, and planners to use in the selection and implementation of appropriate stormwater treatment and source control measures; and
- Provide maintenance procedures to ensure that the selected control measures will be maintained to provide effective, long-term pollution control.

SECTION 2
OVERVIEW AND
USE OF THE PLAN

Introduction

The control measures, often termed Best Management Practices or BMPs, described in this Plan were selected to optimize post-construction, on-site stormwater pollution control. On-site control measures, for the purposes of this Plan, apply to infill and new development project categories listed in the City NPDES permit. Applicable New Development and Redevelopment project categories are listed in Table 2-1 along with the categories of pollutants likely to be present in stormwater runoff from project areas.

Table 2-1. New Development/Redevelopment Project Categories and Associated Pollutants of Concern

New Development and Redevelopment Project Category	Pollutant Category of Concern						
	Sediment	Nutrients	Metals	Trash and Debris	Oxygen Demand	Toxic Organics	Bacteria
Commercial Developments (≥ 100,000 SF)	X	X	X	X	X	X	X
Automotive Repair Shops	X		X	X	X	X	
Retail Gasoline Outlets	X		X	X	X	X	
Restaurants		X		X	X	X	X
Parking Lots (≥ 5,000 SF or 25 spaces)	X		X	X	X	X	
Street and Roads (> 1 acre paved surface)	X		X	X	X	X	
Home Subdivisions (≥ 10 units)	X	X	X	X	X	X	X

X = Pollutant likely to be present in stormwater runoff from project area

A design decision flowchart is presented in Figure 2-1 to aid the user of the Plan in determining what steps need to be completed in the design process to comply with stormwater control requirements. A key step in the process is project assessment to determine expected pollutants (see Table 2-1), receiving water quality and hydraulic conditions, and site conditions (e.g. soils, groundwater, topography), as all these conditions will influence the selection of appropriate treatment control measures. The selection of appropriate control measures should be a collaborative effort between the project proponent and the City stormwater staff. It is recommended that discussions between project planners and engineers and City stormwater staff regarding selection of controls measures occur early in the design process.

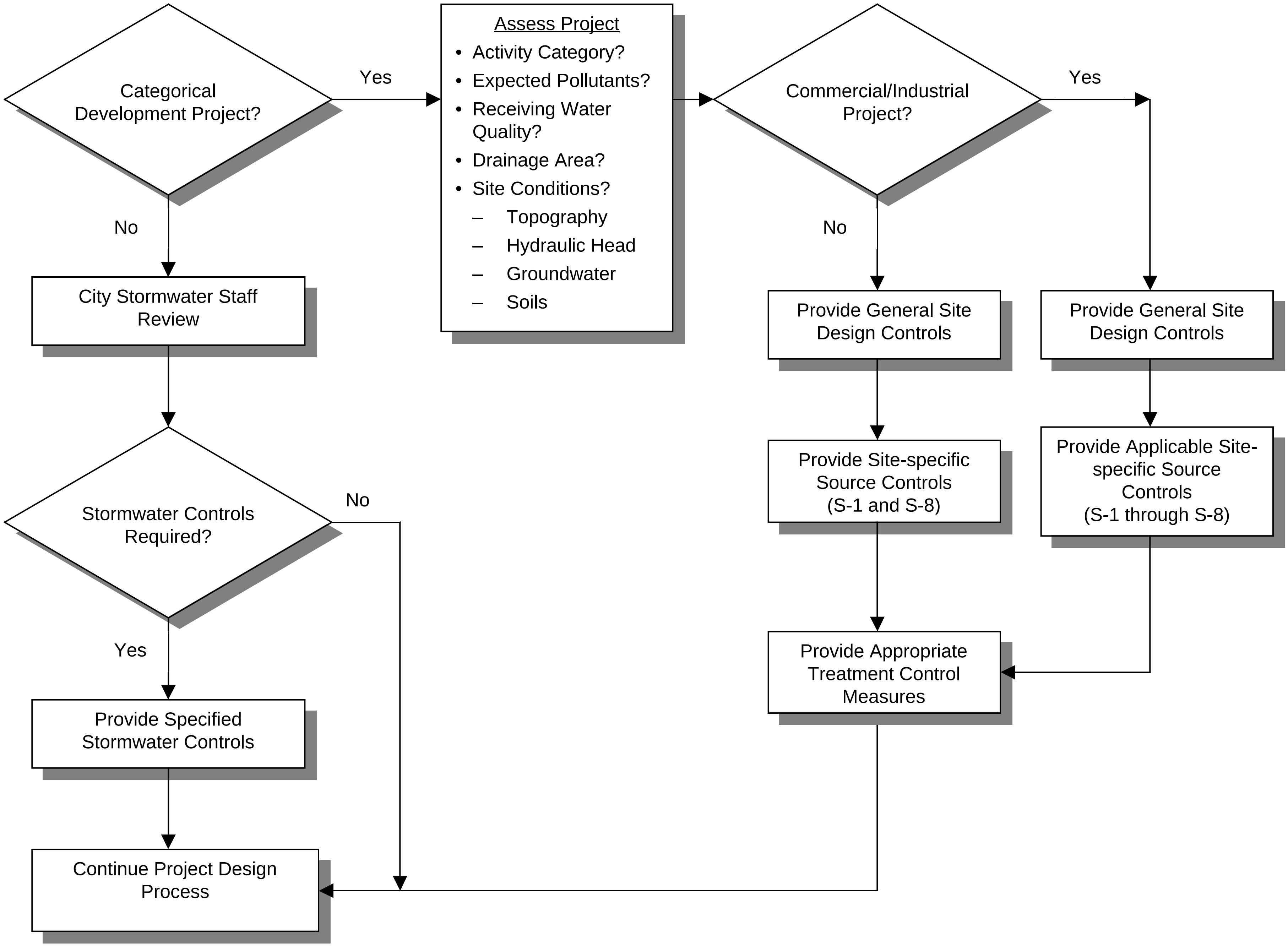


Figure 2-1. Stormwater Controls Design Decision Flowchart

If the project is determined by the City to be a Categorical New Development and Redevelopment project (see Table 2-1), the project must be designed to include the control measures specified in this Plan. Projects that are not New Development and Redevelopment category projects are still subject to City stormwater staff review. Stormwater controls may be required by the City for Non-Categorical New Development and Redevelopment category projects, depending on the potential for discharge of pollutants in stormwater runoff. City staff may accept alternative programs for stormwater pollution control provided such programs can be demonstrated to the satisfaction of City staff that they provide a level of stormwater pollution control equivalent to that provided under this Plan.

Overview of Stormwater Pollution Control Measures

The categories of stormwater pollution controls measures specified in this Plan are summarized in Table 2-2 along with applicable projects and primary objectives of the control measures:

Table 2-2. Summary of Required Stormwater Pollution Controls Measures

Control Measure Category	Applicable Projects	Primary Objective
General Site Design Control Measures	All Categorical New Development/ Redevelopment projects	Minimize the volume and rate of stormwater runoff discharge from the project site.
Site-specific Source Control Measures	Specific outdoor activities and development features: · Outdoor storage area · Trash storage area · Loading/unloading dock area · Repair/maintenance bay · Vehicle/equipment/accessory wash area · Fueling area	Prevent potential pollutants from contacting rainwater or stormwater runoff or to prevent discharge of contaminated runoff to the storm drain system or receiving water.
Treatment Control Measures	All Categorical New Development/ Redevelopment projects – at least one approved treatment control measure required	Remove pollutants from stormwater runoff prior to discharge to the storm drain system or receiving water.

Site design and site-specific source controls are generally the most effective means to control urban runoff pollution because they minimize the need for treatment and are required for all applicable projects. Treatment controls are required in addition to source controls to meet the New Development and Redevelopment requirement to minimize, to the maximum extent practicable, discharge of pollutants to the stormwater conveyance system. Treatment controls are required for all projects, except as noted below, and may be selected from a list of approved methods. Alternative or proprietary treatment controls not described in this Plan may be considered on a case-by-case basis provided the project proponent can demonstrate that treatment equivalent to approved methods is achievable. Alternative control measures are discussed further at the end of Section 5.

New Development and Redevelopment projects that discharge stormwater runoff to City-approved, regional stormwater treatment control facilities that comply with the design requirements of this Plan are not required to provide separate treatment controls. However, such projects are required to provide site design and site-specific source controls in accordance with this Plan. A matrix of New Development and Redevelopment project categories and required stormwater pollution control measures is presented in Table 2-3 to aid the Plan user in determining what controls are required for various project categories. Detailed descriptions and design criteria and procedures for the three types of control measures are presented in fact sheet format in Sections 3, 4, and 5 of the Plan for General Site Design Controls, Site-specific Source Controls, and Treatment Controls, respectively.

Table 2-3. Control Measure Selection Matrix for New Development and Redevelopment Project Categories

New Development and Redevelopment Project Category	General Site Design Control Measures[a]				Site-Specific Source Control Measures[b]								Treatment Control Measures[c]
	Conserve Natural Areas (G-1)	Protect Slopes and Channels (G-2)	Minimize Impervious Area (G-3)	Minimize Effective Imperviousness (G-4) Turf Buffer (G-4.1) Grass-lined Channel (G-4.2)	Storm Drain Message and Signage (S-1)	Out door Storage Area Design (S-2)	Trash Storage Area Design (S-3)	Loading/unloading Dock Area Design (S-4)	Repair/maintenance Bay Design (S-5)	Vehicle/Equipment/ Accessory Washing Area Design (S-6)	Fueling Area Design (S-7)	Proof of Control Measure Maintenance (S-8)	Vegetated Buffer Strip (T-1) Vegetated Swale (T-2) Extended Detention Basin (T-3) Wet Pond (T-4) Constructed Wetland (T-5) Detention Basin/Sand Filter (T-6) Porous Pavement Detention (T-7) Porous Landscape Detention (T-8) Infiltration Basin (T-9) Infiltration Trench (T-10) Media Filter (T-11) Retention/Irrigation (T-12) Proprietary Control Device (T-13)[f]
Commercial Developments (≥ 100,000 SF)	R	R	R	R[e]	R	R[d]	R[d]	R[d]	R[d]	R[d]	R[d]	R	S
Automotive Repair Shops	R	R	R	R[e]	R	R[d]	R[d]	–	R[d]	R[d]	R[d]	R	S
Retail Gasoline Outlets	R	R	R	R[e]	R	R[d]	R[d]	–	R[d]	R[d]	R	R	S
Restaurants	R	R	R	R[e]	R	R[d]	R[d]	R[d]	–	R[d]	–	R	S[g]
Parking Lots (≥ 5,000 SF or 25 spaces)	R	R	R	R[e]	R	R[d]	R[d]	–	–	–	–	R	S
Streets and Roads (> 1 acre paved surface)	R	R	R	R[e]	R	–	–	–	–	–	–	R	S
Home Subdivisions (≥ 10 units)	R	R	R	R[e]	R	R[d]	–	–	–	–	–	R	S

R = Required if applicable to project
R[d] = Required if activity area is included in the project
R[e] = Required unless shown to be infeasible based on site conditions. Select one or more applicable control measures
(a) = Refer to Fact Sheets in Section 3 for detailed information and design criteria
(b) = Refer to Fact Sheets in Section 4 for detailed information and design criteria
(c) = Refer to Fact Sheets in Section 5 for detailed information and design criteria
(f) = Use only on a case-by-case basis with City staff approval or in combination with other applicable treatment control measures
S = Select one or more applicable treatment control measures from list above, unless project discharges runoff to regional treatment facility
S[g] = Restaurants with less than 5,000 SF impervious area not required to provide treatment control mesures

SECTION 3
GENERAL SITE DESIGN
CONTROL MEASURES

Introduction

The principal objective of the General Site Design Control Measures specified in this Plan is to reduce stormwater runoff peak flows and volumes through appropriate site design. The benefits derived from this approach include:

- Reduced size of downstream treatment controls and conveyance systems;
- Reduced pollutant loading to treatment controls; and
- Reduced hydraulic impact on receiving streams.

General Site Design Control Measures include the following design features and considerations designated G-1 through G-4:

- G-1: Conserve Natural Areas
- G-2: Protect Slopes and Channels
- G-3: Minimize Impervious Area
- G-4: Minimize Effective Imperviousness

The General Site Design Control Measures described in this Section are required for all Categorical New Development and Redevelopment projects unless the project proponent demonstrates to the satisfaction of the City that the particular measures are not applicable to the proposed project, or the project site conditions make it infeasible to implement the design control measure in question.

Description

Detailed descriptions and design criteria for each of the General Site Design Control Measures are presented in this Section in fact sheet format.

Conserve Natural Areas

Purpose

Each project site possesses unique topographic, hydrologic and vegetative features, some of which are more suitable for development than others. Locating development on the least sensitive portion of a site and conserving naturally vegetated areas can minimize environmental impacts in general and stormwater runoff impacts in particular.

Design Criteria

If applicable and feasible for the given site conditions, the following site design features or elements are required and should be included in the project site layout, consistent with applicable General Plan and Local Area Plan policies:

1. Concentrate or cluster development on least-sensitive portions of a site, while leaving the remaining land in a natural undisturbed state;
2. Limit clearing and grading of native vegetation at a site to the minimum amount needed to build lots, allow access, and provide fire protection;
3. Maximize trees and other vegetation at each site by planting additional vegetation, clustering tree areas, and promoting the use of native and/or drought-tolerant plants;
4. Promote natural vegetation by using parking lot islands and other landscaped areas;
5. Preserve riparian areas and wetlands.

Protect Slopes and Channels

Purpose

Erosion of slopes and channels can be a major source of sediment and associated pollutants, such as nutrients, if not properly protected and stabilized.

Design Criteria

Slope Protection

Slope protection practices must conform to design requirements or standards set forth by local agency erosion and sediment control standards and design standards. The design criteria described in this fact sheet are intended to enhance and be consistent with these local standards.

1. Slopes must be protected from erosion by safely conveying runoff from the tops of slopes.
2. Slopes must be vegetated (full-cover) with first consideration given to use of native or drought-tolerant species.

Channel Protection

The following measures should be implemented to provide erosion protection of unlined receiving streams. Activities and structures must conform to applicable standards and specifications of agencies with jurisdiction (e.g. U.S. Army Corps of Engineers, California Department of Fish and Game).

1. Utilize natural drainage systems to the maximum extent practicable, but minimize runoff discharge rate and volume to the maximum extent practicable.
2. Stabilize permanent channel crossings.
3. In cases where beds and/or banks of receiving streams are fragile and particularly susceptible to erosion, special stabilization may be required.
   a. Small grade control structure (e.g. drop structure) may be used to reduce the slope of the channel.
   b. Severe bends or cut banks may need to be hardened by lining with grass or rock.
   c. Rock-lined, low-flow channels may be appropriate to protect fragile beds.
4. Install energy dissipaters, such as rock riprap, at the outlets of storm drains, culverts, conduits or channels that discharge into unlined channels.

Purpose

The potential for discharge of pollutants in stormwater runoff from a project site increases as the percentage of impervious area within the project site increases. Impervious areas increase the volume and rate of runoff flow. Pollutants deposited on impervious areas tend to be easily mobilized and transported by runoff flow. Minimizing impervious area through site design is an important means of minimizing stormwater pollutants of concern. In addition to the environmental and aesthetic benefits, a highly pervious site may allow reduction in the size of downstream conveyance and treatment systems, yielding savings in development costs.

Design Strategies

Some aspects of site design are directed by local agency building and fire codes and ordinances. The design strategies suggested in this fact sheet are intended to enhance and be consistent with these local codes and ordinances. Maximizing perviousness at every possible opportunity requires integration of many small strategies. Suggested strategies for minimizing imperviousness through site design include the following:

1. Reduce the foot prints of building and parking lots;
2. Cluster buildings and paved areas to maximize pervious area;
3. Use minimum allowable roadway and sidewalk cross sections, driveway lengths and parking stall widths;
4. Include landscape islands in cul-de-sacs (where approved);
5. Maximize tree preservation or tree planting;
6. Preserve soils with high infiltration rates;
7. Use pervious pavement materials where appropriate, such as modular paving blocks, turf blocks, porous concrete and asphalt, brick, and gravel or cobbles. (Ref. BASMAA, 1999 for descriptions of pervious pavements options.)
8. Use grass-lined channels or surface swales to convey runoff instead of paved gutters. (See Fact Sheet G-4.2)

Design Criteria

The City has established the following maximum runoff coefficients as goals for the various types of development listed in Table 3-1. Use of higher values may be permitted for individual projects upon demonstration to the satisfaction of the City stormwater review staff that lower values cannot be feasibly achieved.

Table 3-1. Design Criteria Goals for Project Site Runoff Coefficients

Development Type	Maximum Runoff Coefficient
Residential	0.30
High Density Residential	0.60
Commercial	0.70-0.85
Industrial	0.85

Minimize Effective Imperviousness

Purpose

Stormwater runoff flows from impervious areas typically contain higher concentrations of pollutant and higher peak flows than flows from equally-sized pervious areas. The impacts of flow from impervious areas can be reduced by employing a design strategy termed “minimizing effective imperviousness”. This approach involves routing runoff from impervious areas over grassy areas or other pervious areas prior to discharge to the storm drainage system or receiving water to reduce peak flows, reduce total runoff volume and provide some degree of pollutant removal. In addition to the environmental and aesthetic benefits, minimizing effective imperviousness may allow reduction in the size of downstream conveyance and treatment systems, yielding savings in development costs. Projects that employ the approaches described in this fact sheet in accordance with the specified design criteria will be allowed to reduce the value of the effective impervious ratio used later in this Plan to size treatment controls. Calculation of effective imperviousness is described later in this fact sheet.

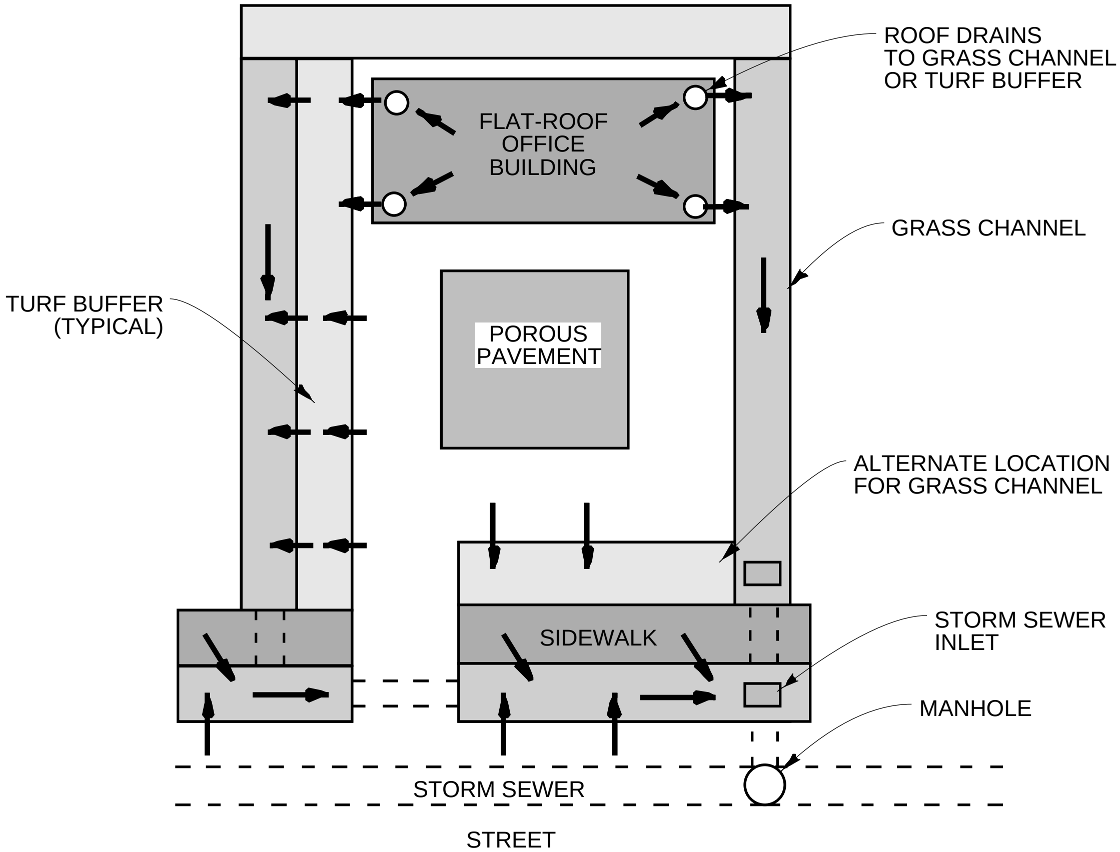
Description and Design

Suggested design strategies to minimize effective imperviousness include G-4.1: Turf Buffer and G-4.2: Grass-lined Channel. Suggested uses of these design strategies are illustrated in Figure 3-1. These design control measures are described below along with associated design criteria. It is important to note that at least one of these control measures is required to be employed in the site design unless site conditions make it infeasible to do so. For this site design requirement to be waived, project proponents must demonstrate infeasibility to the satisfaction of the City stormwater review staff.

G-4.1: Turf Buffers

Description

Turf Buffers are uniformly graded and densely vegetated strips of turf grass. Runoff flow is distributed uniformly across the top width of the strip to achieve sheet flow down the length of the strip. Turf Buffers provide opportunity for infiltration, reduce peak flows from impervious areas and provide some degree of pollutant removal. Applications of Turf Buffers are illustrated in Figure 3-2. Turf Buffers differ from Grass-lined Channels, as they are designed to receive and maintain sheet flow as opposed to concentrated or channelized flow. Sheet flow application to the top of the Turf buffer may achieved by routing sheet flow from impervious areas, such as parking lots, directly to the top of the Turf Buffer or by redistributing concentrated flow across the top of the Turf Buffer by means of a level spreader. Turf Buffer strips, used for the purpose of minimizing effective imperviousness, are similar to Grass Strip Filters employed as a treatment control (see Section 5, Fact Sheet T-1), but differ in terms of the values used for the two principal design parameters – linear application rate (across the top width of the buffer) (cfs/ft width) and down-slope length.



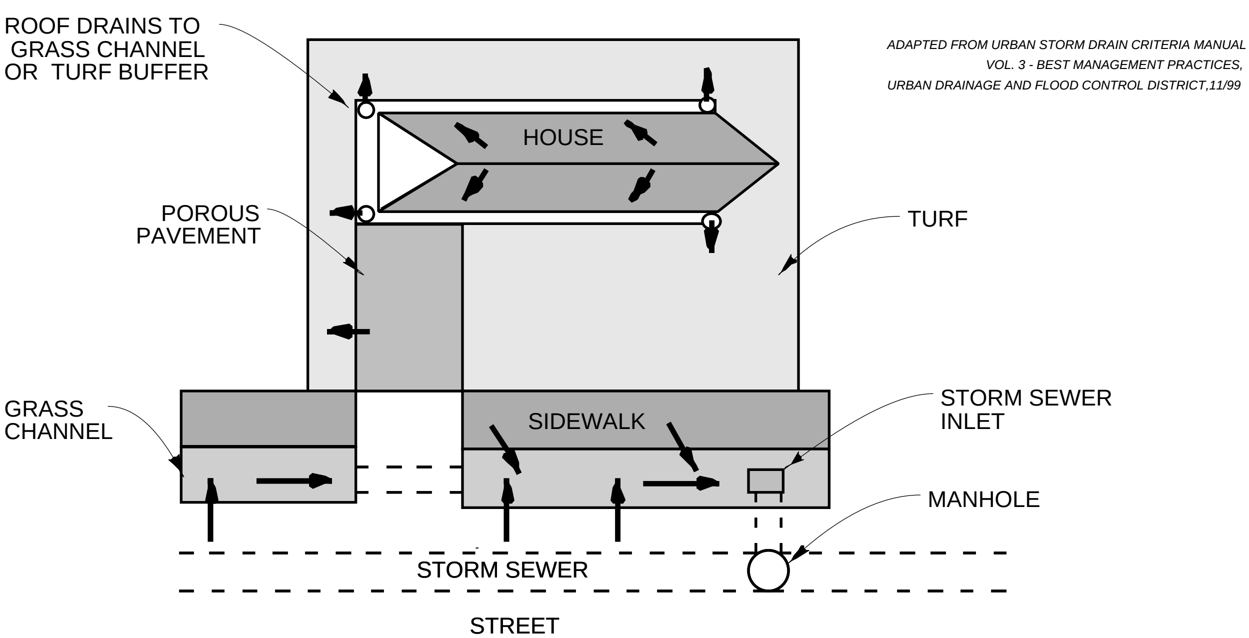


Figure 3-1 Examples of Minimizing Flow From Impervious Area

General Application and Design Considerations

Turf Buffers are appropriate for use in residential, commercial, industrial and institutional settings as illustrated in Figure 3-1. They are typically located adjacent to impervious areas to be mitigated. Their use should be incorporated into the site and master drainage planning and their design should be performed in close coordination with the landscape architect. The contributing flow from impervious areas that can be accommodated by the Turf Buffer will be limited according to the design criteria in this fact sheet. Tributary areas are typically less than 5 acres. Several Turf Buffers may be used on a single site, each sized according to the impervious area from which it receives flow. Irrigation and regular mowing are required to maintain the turf grass cover. Turf Buffers should be located away from, or protected from, excessive pedestrian or vehicular traffic that can damage the grass cover and adversely affect achievement of sheet flow over the surface. Although Turf Buffers provide some degree of pollutant removal, they do not qualify as treatment controls and must be followed by at least one of the approved treatment controls described in Section 5.

Design Criteria and Procedure

Principal design criteria for Turf Buffers are summarized in Table 3-2. See Figure 3-2 for dimensional relationships.

Table 3-2. Turf Buffer Design Criteria

Design Parameter	Unit	Design Criteria
Design Flow (SQDF)	cfs	0.20 in/hr × C × A
Maximum linear application rate (q_a)	cfs/ft width	0.05
Minimum width (normal to flow) (W_{TB})	ft	(SQDF)/(q_a)
Minimum length (flow direction) (L_{TB})	ft	8 (minimum)
Maximum slope (flow direction) (S_{TB})	%	4 (maximum)
Vegetation	–	Turf grass (irrigated)

Design procedure and application of design criteria are outlined in the following steps:

1. Design Flow — Determine Stormwater Quality Design Flow (SQDF) in cfs for impervious area to be mitigated.

   $$SQDF = 0.20\ \text{in/hr} \times C \times \text{Area}$$

2. Minimum Width — Calculate minimum width of the Turf Buffer (W_{TB}) normal to flow direction.

   $$W_{TB} = (SQDF)/(q_a)$$

   $$W_{TB} = (SQDF)/0.05\ \text{cfs/ft (minimum)}$$

3. Minimum Length — Length of the Turf Buffer (L_{TB}) in the direction of flow shall not be less than 8 feet.

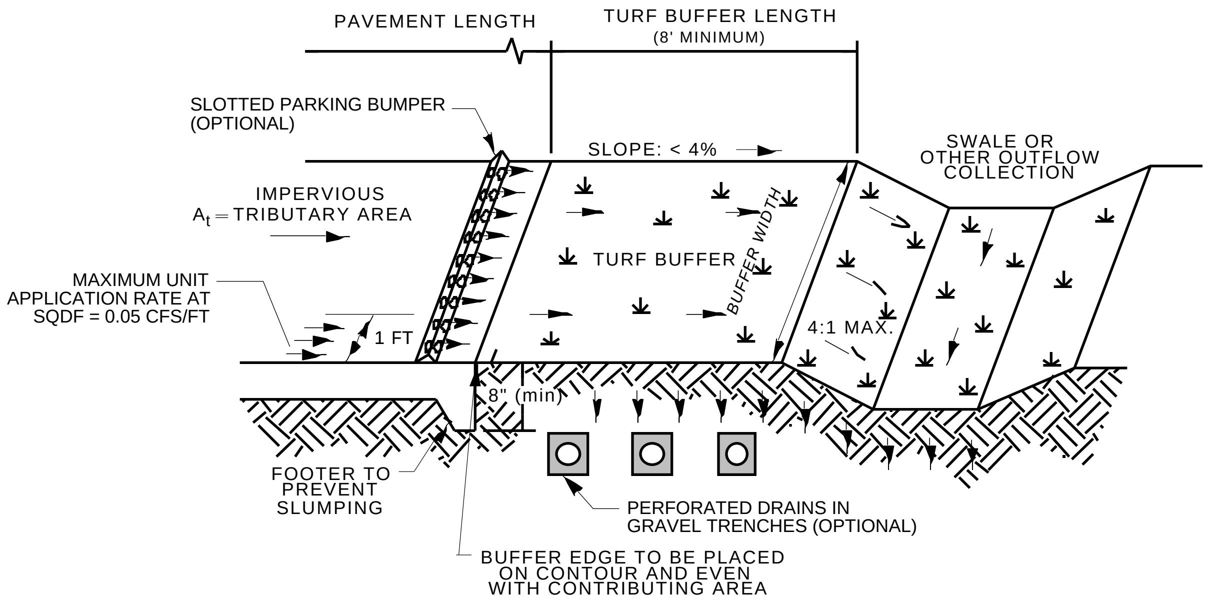
   $$L_{TB} = 8\ \text{feet (minimum)}$$

4. Maximum Slope — Slope of the ground in the direction of flow shall not be greater than 4 percent.

5.	Flow Distribution	Incorporate a device at the upstream end of the Turf Buffer to evenly distribute flows along the top width, such as slotted curbing, modular block porous pavement, or other spreader devices. Concentrated flow delivered to the Turf Buffer must be distributed evenly by means of a level spreader or similar concept.
6.	Vegetation	Provide irrigated perennial turf grass to yield full, dense cover (See Appendix F for suitable grasses).
7.	Outflow Collection	Provide a means for outflow collection and conveyance (e.g. grass channel/swale, storm drain, street gutter).

<u>Design Example</u>

A completed design form follows as a design example. Blank design forms are provided in Appendix G.



SHEET FLOW CONTROL

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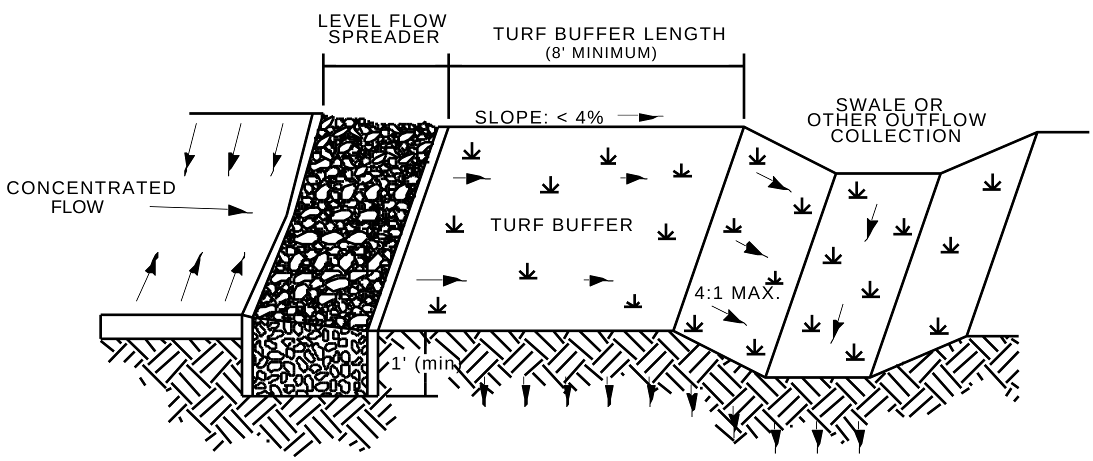


CONCENTRATED FLOW CONTROL

NOT TO SCALE

Figure 3-2 TURF BUFFER

Design Procedure Form for G-4.1: Turf Buffer

Designer: ____________________

Company: ____________________

Date: ____________________

Project: ____________________

Location: ____________________

1. Design Flow	SQDF = 1.0 cfs
2. Design Width W_{TB} = (SQDF)/0.05 cfs/ft.	W_{TB} = 20.0 ft.
3. Design Length (8 ft minimum)	L_{TB} = 8.0 ft.
4. Design Slope (4 % maximum)	S_{TB} = 3.0 %
5. Flow Distribution (Check type used or describe "Other")	X Slotted curbing ___ Modular block porous paving ___ Level spreader ___ Other ___
6. Vegetation (describe type)	Tall fescue
7. Outflow Collection (Check type used or describe "Other")	X Grass Channel/Swale ___ Street Gutter ___ Storm Sewer ___ Underdrain used ___ Other ___

Notes: ____________________

G-4.2: Grass-lined Channels

Description

Grass-lined Channels are densely vegetated drainageways with gentle sideslopes and gradual longitudinal slopes in the direction of flow that collect and slowly convey runoff to downstream points of discharge. Grass-lined Channels provide an opportunity for infiltration, reduce peak flows from impervious areas and provide some degree of pollutant removal. Applications of Grass-lined Channels are illustrated in Figure 3-3. Grass-lined Channels, used for the purpose of minimizing effective imperviousness, are similar to Grass Swale Filters employed as a treatment control (see Section 5, Fact Sheet T-1), but differ in terms of design depth of flow and minimum contact time.

General Application and Design Considerations

Grass-lined Channels are appropriate for use in residential, commercial, industrial and institutional settings as illustrated in Figure 3-1. They are typically used in conjunction with Turf Buffers and are located adjacent to impervious areas to be mitigated. Their use should be incorporated into the site and master drainage planning. The contributing flow from impervious areas that can be accommodated by the Grass-lined Channels will be limited according to the design criteria in this fact sheet. Tributary areas are typically less than 5 acres. Several Grass-lined Channels may be used on a single site, each sized according to the impervious area from which it receives flow. Irrigation and regular mowing are required to maintain the turf grass cover. Grass-lined Channels are not the same as Grass Swale Filters. Consequently, Grass-lined Channels do not qualify as treatment controls and must be followed by at least one of the approved treatment controls described in Section 5.

Design Criteria and Procedure

Principal design criteria for Grass-lined Channels are summarized in Table 3-3 (Ref. Figure 3-3).

Table 3-3 Grass-lined Channel Design Criteria

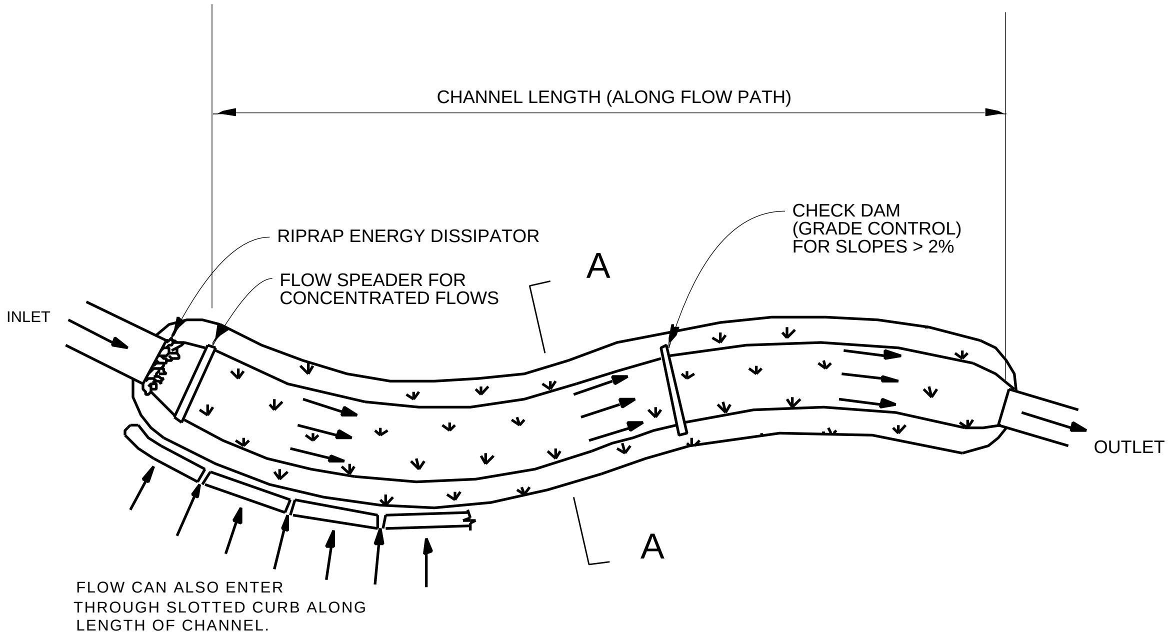
Design Parameter	Unit	Design Criteria
Design Flow (SQDF)	cfs	0.20 in/hr _ C _ Area
Channel geometry	–	Trapezoidal or triangular
Maximum channel side slope	H:V	4 :1
Minimum slope in flow direction	%	0.2 (provide underdrains for slopes < 0.5)
Maximum slope in flow direction	%	2.0 (provide grade-control checks for slopes >2.0)
Maximum flow velocity	ft/sec	1.5 (based on Manning’s n = 0.05)
Maximum depth of slow at SQDF	ft	2.0 (based on Manning’s n = 0.05)
Vegetation	–	Turf grass

Design procedure and application of design criteria are outlined in the following steps:

1.	Design Flow	Determine Stormwater Quality Design Flow (SQDF) for impervious area to be mitigated. $\text{SQDF} = 0.20 \text{ in/hr} \times C \times \text{Area}$
2.	Channel Geometry	Use trapezoidal or triangular cross section.
3.	Maximum Side Slope	Side slopes shall not be steeper than 4:1 (5:1 or flatter preferred).
4.	Minimum Side Slope	Slope of the channel in the direction of flow shall not be less than 0.2 percent. Channel with slopes less than 0.5 percent should be provided with underdrains (see Figure 3-3).
5.	Maximum Slope	Slope of the channel in the direction of flow shall not be greater than 2 percent. Provide grade control checks for slopes greater than 2.0 percent (see Figure 3-3).
6.	Flow Velocity	Maximum flow velocity at design flow should not exceed 1.5 ft/sec based on a Manning's n = 0.05.
7.	Flow Depth	Maximum depth of flow at design flow should not exceed 2.0 feet based on a Manning's n = 0.05.
8.	Vegetation	Provide irrigated perennial turf grass to yield full, dense cover. (See Appendix F for suitable grasses.)
9.	Drainage & Flood Control	Provide sufficient flow depth for flood event flows to avoid flooding of critical areas or structures.

<u>Design Example</u>

A completed design form follows as a design example. Blank design forms are provided in Appendix G.



TRAPEZOIDAL GRASS -LINED CHANNEL – PLAN

NOT TO SCALE

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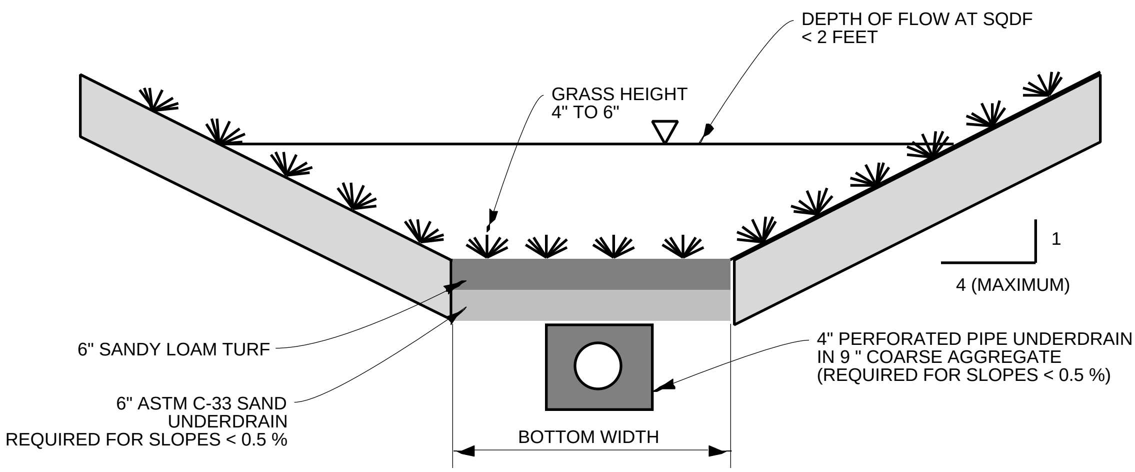
VOL. 3 - BEST MANAGEMENT PRACTICES,
URBAN DRAINAGE AND FLOOD CONTROL DISTRICT,11/99



TRAPEZOIDAL GRASS-LINED CHANNEL – SECTION

NOT TO SCALE

Figure 3-3 GRASS-LINED CHANNEL

Design Procedure Form for G-4.2: Grass-lined Channel

Designer: ______________________________

Company: ______________________________

Date: ______________________________

Project: ______________________________

Location: ______________________________

1. Design Flow	SQDF = 10.0 cfs
2. Channel Geometry	
A. Channel Bottom Width (b)	b = 20.0 ft.
B. Side slope (Z)	Z = 4:1
3. Depth of flow at SQDF (d) (2 ft max, Manning n= 0.05)	d = 1.4 ft.
4. Design Slope	
A. s = 2 percent maximum	s = 0.32 %
B. No. of grade controls required	______ (number)
6. Vegetation (describe)	Tall Fescue
7. Outflow Collection (Check type used or describe "Other")	X Grated Inlet ____ Infiltration Trench ____ Other ______________

Notes ______________________________

Calculating Effective Imperviousness

The effective imperviousness of a site may be reduced if flow from impervious areas is routed over general site design controls G-4.1: Turf Buffers and/or G-4.2: Grass-lined Channels that are designed in conformance to the criteria presented in this fact sheet.

Calculation Procedure

The allowable reduction in impervious percentage is determined with the use of Figure 3-4 as described in the following steps:

1. Estimate the total imperviousness (impervious percentage) of the site by the determining the weighted average of individual areas of like imperviousness. Table 3-4 may be used as guide for estimating imperviousness of typical site elements.

Table 3-4. Recommended Percent Imperviousness for Typical Site Elements

Site Element	Percent Imperviousness
Asphalt/concrete pavement	100
Gravel pavement	40
Roofs	90
Porous pavement	35[1]
Lawn/turf	0
Open space	0

[1]Variable with product type, assumes porous subsoil and use of underdrains

Table 3-5 may be used as an aid in calculating total imperviousness.

Table 3-5. Calculation Sheet for Determination of Total Imperviousness

Site Element	Unit Area (ft^2)	Percent Imperviousness	Weighting Factor[2]	Weighted % Imperviousness [3,4]
Asphalt/concrete pavement		100		
Gravel pavement		40		
Roofs		90		
Porous pavement		35[5]		
Lawn/turf		0		
Open space		0		
Total Contributing Area[1]		–	–	

[1]Total contributing area = sum of unit areas
[2]Weighting factor = unit area / total contributing area
[3]Weighted imperviousness = weighing factor X percent imperviousness
[4]Total imperviousness = sum of weighted imperviousness
[5]Variable with product type, assumes porous subsoil and use of underdrains

2. Enter Figure 3-4 along the horizontal axis with the value of total imperviousness calculated in Step 1. Move vertically up Figure 3-4 until the appropriate curve (G-4.1 or G-4.2 employed individually or G-4.1 and G-4.2 employed together) is intercepted. Move horizontally across Figure 3-4 until the vertical axis is intercepted. Read the Effective Imperviousness value along the vertical axis.

   Note that if G-4.1 and/or G-4.2 are implemented on only a portion of the site, the site may be divided and effective imperviousness determined for the portion of the site for which site design controls have been implemented. The resulting effective imperviousness may be combined with total imperviousness of the remainder of the site to determine a weighted average total imperviousness for the entire site.

Calculation Example

The calculation procedure described above is illustrated by the following example.

<u>Design Conditions:</u>

1. All flow from impervious areas is routed over a Turf Buffer (G-4.1).
2. The site consists of the site elements and associated unit areas shown in Table 3-6.

Table 3-6. Example Calculation Sheet for Determination of Total Imperviousness

Site Element	Unit Area (ft^2)	Percent Imperviousness	Weighting Factor[4]	Weighted % Imperviousness[5,6]
Asphalt/concrete pavement	10,000	100	0.20	20
Gravel pavement	0	40		
Roofs	10,000	90	0.20	18
Porous pavement	0	35		
Lawn	20,000	0	0.40	0
Open space	10,000	0	0.20	0
Total Contributing Area[3]	50,000	–	–	38

<u>Calculations:</u>

3. Total contributing area = sum of unit areas
4. Weighting factors = unit area/total contributing area
5. Weighted imperviousness = weighing factor × percent imperviousness
6. Total imperviousness = sum of weighted imperviousness
7. Effective imperviousness = 32 percent (from Figure 3-4)

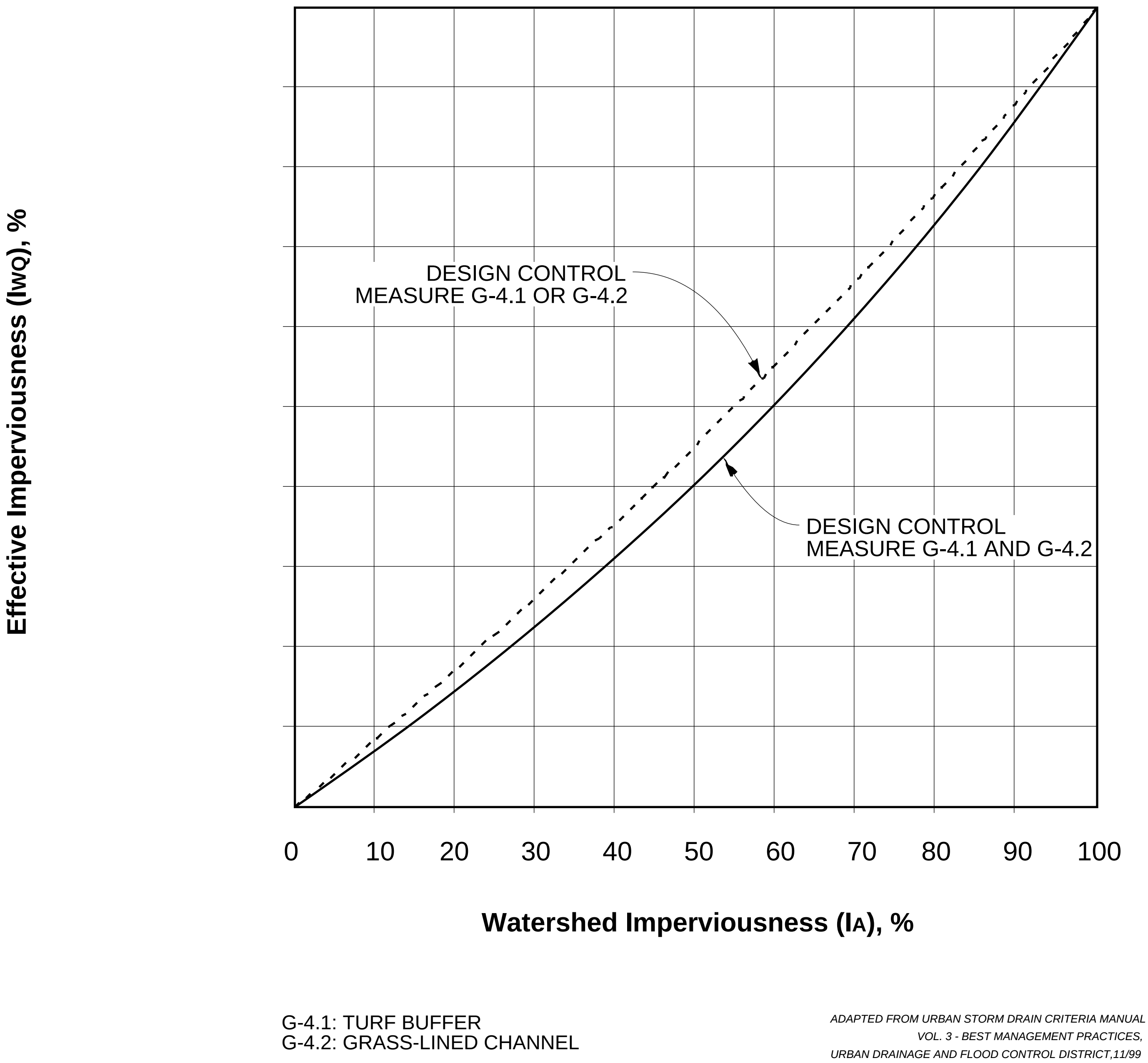


Figure 3-4. DETERMINATION OF EFFECTIVE IMPERVIOUSNESS

SECTION 4
SITE-SPECIFIC SOURCE CONTROL MEASURES

Introduction

Source control measures are low-technology practices designed to prevent pollutants from contacting stormwater runoff or to prevent discharge of contaminated runoff to the storm drainage system. This Section addresses site-specific, structural type source control measures consisting of specific design features or elements. Non-structural type source control measures; such as good housekeeping and employee training are not included in this Plan. The California Stormwater Best Management Practices Handbooks may be consulted for information on non-structural type source control measures practice (CASQA, 2003). The City may require additional source control measures not included in this Plan for specific pollutants, activities or land uses.

This Section describes control measures for specific types of sites or activities that have been identified as potential significant sources of pollutants in stormwater. Each of the measures specified in this Section should be implemented in conjunction with appropriate nonstructural source control measures to optimize pollution prevention.

The measures addressed in this section apply to both stormwater and non-stormwater discharges. Non-stormwater discharges are the discharge of any substance, such as cooling water, process wastewater, etc., to the storm drainage system or water body that is not composed entirely of stormwater. Stormwater that is mixed or commingled with other non-stormwater flows is considered non-stormwater. Discharges of stormwater and non-stormwater to the storm drainage system or a water body may be subject to local, state, or federal permitting prior to any discharge commencing. The appropriate agency should be contacted prior to any discharge. Discuss the matter with the stormwater staff if you are uncertain as to which agency should be contacted.

Some of the measures presented in this Section require connection to the sanitary sewer system. Connection and discharge to the sanitary sewer system without prior approval or obtaining the required permits is prohibited. Contact the City stormwater staff to obtain information regarding obtaining sanitary sewer permits from the City. Discharges of certain types of flows to the sanitary sewer system may be cost prohibitive. The designer is urged to contact the City prior to completing site and equipment design of the facility.

Description

Site-specific source control measures and associated design features specified for various sites and activities are summarized in Table 4-1. Fact sheets are presented in this section for each source control measure. These sheets include design criteria established by the City to ensure effective implementation of the required source control measures:

Table 4-1. Summary of Site-specific Source Control Design Features

Site-specific Source Control Measure[1]	Design Feature or Element						
	Signs, placards, stencils	Surfacing (compatible, impervious)	Covers, screens	Grading/berming to prevent run-on	Grading/berming to provide secondary containment	Sanitary sewer connection	Emergency Storm Drain Seal
Storm Drain Message and Signage (S-1)	X						
Outdoor Material Storage Area Design (S-2)		X	X	X	X		X
Outdoor Trash Storage and Waste Handling Area Design (S-3)		X	X	X		X	
Outdoor Loading/Unloading Dock Area Design (S-4)		X	X	X	X		
Outdoor Repair/Maintenance Bay Design (S-5)		X	X	X	X		X
Outdoor Vehicle/Equipment/ Accessory Washing Area Design (S-6)		X	X	X	X	X	X
Fueling Area Design (S-7)		X	X	X	X		X
Parking Lot Design[2]							

[1]Refer to Fact Sheets in Section 4 for detailed information and design criteria
[2]Requirements for proper design of parking lots are covered by requirements for General Site Design Control Measures (see Section 3) and Treatment Control Measures (see Section 5).

Purpose

Waste materials dumped into storm drain inlets can have severe impacts on receiving and ground waters. Posting notices regarding discharge prohibitions at storm drain inlets can prevent waste dumping. This fact sheet contains details on the installation of storm drain messages at storm drain inlets located in new or redeveloped commercial, industrial, and residential sites.

Design Criteria

Storm drain messages have become a popular method of alerting the public about the effects of and the prohibitions against waste disposal into the storm drain system. The signs are typically stenciled or affixed near the storm drain inlet. The message simply informs the public that dumping of wastes into storm drain inlets is prohibited and/or the drain discharges to a receiving water.

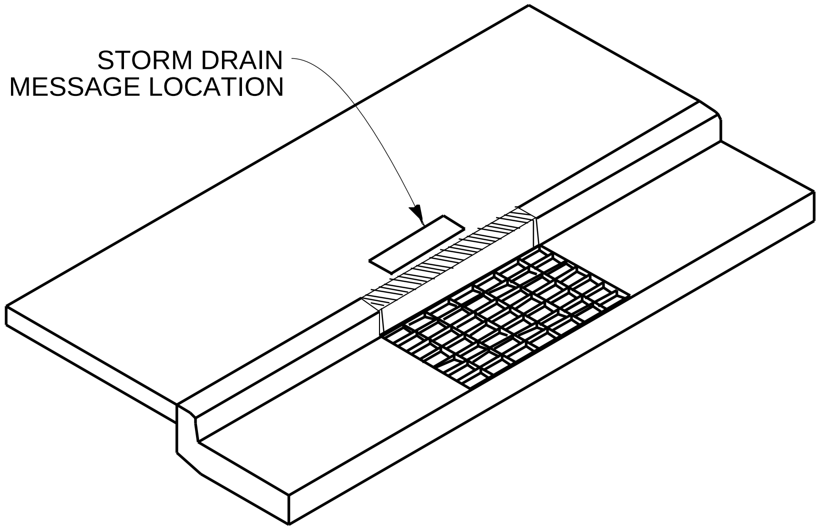
Storm drain message markers or placards are required at all storm drain inlets within the boundary of the development project. The marker should be placed in clear sight adjacent to the inlet (see Figure 4-1). All storm drain inlet locations must be identified on the development site map.

The City has developed standards for design and installation of storm drain messages and signs (See City "Red Book" Standards). Consult the City stormwater staff to determine specific requirements for storm drain messages.

Signs with language and/or graphical icons, which prohibit illegal dumping, shall be posted at designated public access points along channels and streams within a project area. Consult the City stormwater staff to determine specific signage requirements.

Maintenance Requirements

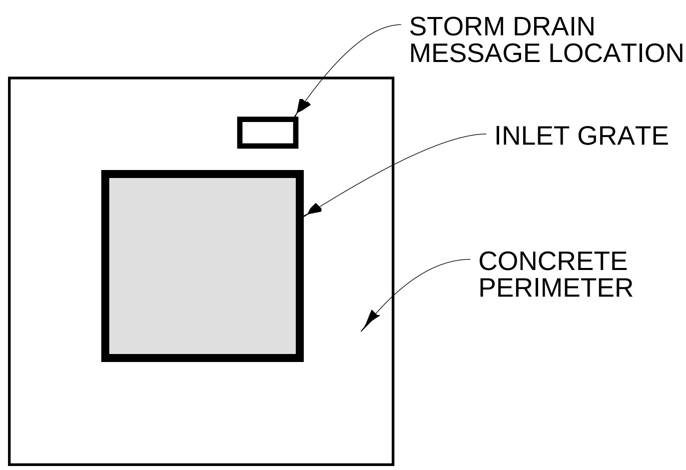
Legibility of markers and signs shall be maintained. If required by the City, the owner/operator or homeowner's association shall enter into a maintenance agreement with the agency or record a deed restriction upon the property title to maintain the legibility of messages and signs.



CURB TYPE INLET

NOTES:

1. **STORM DRAIN MESSAGE SHALL BE APPLIED IN SUCH A WAY AS TO PROVIDE A CLEAR, LEGIBLE IMAGE.**
2. **STORM DRAIN MESSAGE SHALL BE PERMANENTLY APPLIED DURING THE CONSTRUCTION OF THE CURB AND GUTTER USING A METHOD APPROVED BY THE LOCAL AGENCY.**



AREA TYPE INLET

Figure 4-1. Storm Drain Message Location

Outdoor Material Storage Area Design

Purpose

Materials that are stored outdoors can become sources of pollutants in stormwater runoff if not handled or stored properly. Materials can be in the form of raw products, by-products, finished products, and waste products. The type of pollutants associated with the materials will vary depending on the type of commercial or industrial activity.

Some materials are more of a concern than others. Toxic and hazardous materials must be prevented from coming in contact with stormwater. Non-toxic or non-hazardous materials do not have to be prevented from stormwater contact. However, these non-toxic or non-hazardous materials may have toxic effects on receiving waters if allowed to be discharged with stormwater in significant quantities. Accumulated material on an impervious surface could result in significant debris and sediment being discharged with stormwater runoff causing a significant impact on the rivers or streams that receive the runoff.

Materials may be stored in a variety of ways, including bulk piles, containers, shelving, stacking, and tanks. Stormwater contamination may be prevented by eliminating the possibility of stormwater contact with the material storage areas either through diversion, cover, or capture of the stormwater. Control measures may also include minimizing the storage area. Control measures are site specific, and must meet City requirements.

Design Criteria

Design requirements for material storage areas are governed by Building and Fire Codes, and by current City or County ordinances and zoning requirements. Source controls described in the fact sheet are intended to enhance and be consistent with these code and ordinance requirements. The following design features should be incorporated into the design of material storage area when storing materials outside that will contribute significant pollutants to the storm drain.

Source Control Design Feature	Design Criteria
Surfacing	· Construct the storage area base with a material impervious to leaks and spills.
Covers	· Install a cover that extends beyond the storage area, or use a manufactured storage shed for small containers.
Grading/Containment	· Minimize the storage area. · Slope the storage area towards a dead-end sump to contain spills. · Grade or berm storage areas to prevent run-on from surrounding areas. · Direct runoff from downspouts/roofs away from storage areas.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

Purpose

Stormwater runoff from areas where trash is stored or disposed of can be polluted. In addition, loose trash and debris can be easily transported by water or wind into nearby storm drain inlets, channels, and/or creeks. Waste handling operations that may be sources of stormwater pollution include dumpsters, litter control, and waste piles. This fact sheet contains details on the specific measures required to prevent or reduce pollutants in stormwater runoff associated with trash storage and handling.

Design Criteria

Design requirements for waste handling areas are governed by Building and Fire Codes, and by current local agency ordinances and zoning requirements. The design criteria described in the fact sheet are meant to enhance and be consistent with these code and ordinance requirements. Hazardous waste should be handled in accordance with legal requirements established in Title 22, California Code of Regulations.

Wastes from commercial and industrial sites are typically hauled away for disposal by either public or commercial carriers that may have design or access requirements for waste storage areas. The design criteria listed below are recommendations and are not intended to be in conflict with requirements established by the waste hauler. The waste hauler should be contacted prior to the design of your site trash collection area. Conflicts or issues should be discussed with the City staff.

The following trash storage area design controls were developed to enhance the local agency codes and ordinances and should be implemented depending on the type of waste and the type of containment:

Source Control Design Feature	**Design Criteria**
Surfacing	· Construct the storage area base with a material impervious to leaks and spills.
Screens/Covers	· Install a screen or wall around trash storage area to prevent off-site transport of loose trash. · Use lined bins or dumpsters to reduce leaking of liquid wastes. · Use water-proof lids on bins/dumpsters or provide a roof to cover enclosure (City discretion) to prevent rainfall from entering containers
Grading/Contouring	· Berm or grade the waste handling area to prevent run-on of stormwater. · Do not locate storm drains in immediate vicinity of the trash storage area.
Signs	· Post signs on all dumpsters informing users that hazardous materials are not to be disposed of therein.

Maintenance Requirements

The integrity of structural elements that are subject to damage (e.g. screens, covers, and signs) must be maintained by the owner/operator. Maintenance agreements between the City and the owner/operator may be required. If required by the City, maintenance agreements or deed restrictions must be executed by the owner/operator before improvement plans are approved. Refer to Appendix C and D for a further guidance regarding maintenance plans agreements.

Purpose

Materials spilled, leaked, or lost during loading or unloading may collect on impervious surfaces or in the soil and be carried away by runoff or when the area is cleaned. Also, rainfall may wash pollutants from machinery used to load or unload materials. Depressed loading docks (truck wells) are contained areas that can accumulate stormwater runoff. Discharge of spills or contaminated stormwater to the storm drain system is prohibited. This fact sheet contains details on specific measures recommended to prevent or reduce pollutants in stormwater runoff from outdoor loading or unloading areas.

Design Criteria

Design requirements for outdoor loading/unloading of materials are governed by Building and Fire Codes, and by current local agency ordinances and zoning requirements. Source controls described in the fact sheet are meant to enhance and be consistent with these code and ordinance requirements. Companies may have their own design or access requirements for loading docks. The design criteria listed below are not intended to be in conflict with requirements established by individual companies. Conflicts or issues should be discussed with the City staff.

The following design criteria should be followed when developing construction plans for material loading/unloading areas:

Source Control Design Feature	Design Criteria
Surfacing	· Construct floor surfaces with material that is compatible with materials being handled in the loading/unloading area.
Covers	· Cover loading/unloading areas to a distance of at least 3 feet beyond the loading dock or install a seal or door skirt to be used for all material transfers between the trailer and the building.
Grading/Contouring	· Grade or berm storage areas to prevent run-on from surrounding areas. · Direct runoff from downspouts/roofs away from loading areas.
Emergency Storm Drain Seal	· Do not locate storm drains in the loading dock area. Direct connections to storm drains from depressed loading docks are prohibited. · Provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the storm drainage system.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces, such as depressed loading docks. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

Purpose

Activities that can contaminate stormwater include engine repair, service and parking (leaking engines or parts). Oil and grease, solvents, car battery acid, coolant and gasoline from the repair/maintenance bays can severely impact storm water if allowed to come into contact with storm water runoff. This fact sheet contains details on the specific measures required to prevent or reduce pollutants in stormwater runoff from vehicle and equipment maintenance and repair areas.

Design Criteria

Design requirements for vehicle maintenance and repair areas are governed by Building and Fire Codes, and by current local agency ordinances, and zoning requirements. The design criteria described in the fact sheet are meant to enhance and be consistent with these code requirements.

The following design criteria are required for vehicle and equipment maintenance, and repair. All hazardous and toxic wastes must be prevented from entering the storm drainage system.

Source Control Design Feature	Design Criteria
Surfacing	· Construct the vehicle maintenance/repair floor area with Portland cement concrete.
Covers	· Cover or berm areas where vehicle parts with fluids are stored. · Cover or enclose all vehicle maintenance/repair areas.
Grading/Contouring	· Berm or grade the maintenance/repair area to prevent run-on and runoff of stormwater or runoff of spills. · Direct runoff from downspouts/roofs away from maintenance/repair areas. · Grade the maintenance/repair area to drain to a dead-end sump for collection of all wash water, leaks and spills. Direct connection of maintenance/repair area to storm drain system is prohibited. · Do not locate storm drains in the immediate vicinity of the maintenance/repair area.
Emergency Storm Drain Seal	· Provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the storm drainage system.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

Outdoor Vehicle/Equipment/Accessory Washing Area Design

Purpose

Washing vehicles and equipment in areas where wash water flows onto the ground can pollute storm water. Wash waters can contain high concentrations of oil and grease, solvents, phosphates and high suspended solids loads. Sources of washing contamination include outside vehicle/equipment cleaning or wash water discharge to the ground. This fact sheet contains details on the specific measures required to prevent or reduce pollutants in stormwater runoff from vehicle and equipment washing areas.

Design Criteria

Design requirements for vehicle and equipment washing areas are governed by Building and Fire Codes, and by current local agency ordinances, and zoning requirements. The design criteria described in the fact sheet are meant to enhance and be consistent with these code requirements.

The following design criteria are required for vehicle and equipment washing areas. All hazardous and toxic wastes must be prevented from entering the storm drain system.

Source Control Design Feature	Design Criteria
Surfacing	· Construct the vehicle/equipment wash area floors with Portland cement concrete.
Covers	· Provide a cover that extends over the entire wash area.
Grading/Contouring	· Berm or grade the maintenance/repair area to prevent run-on and runoff of stormwater or runoff of spills. · Grade or berm the wash area to contain the wash water within the covered area and direct the wash water to treatment and recycle or pretreatment and proper connection to the sanitary sewer system. Obtain approval from the City before discharging to the sanitary sewer. · Direct runoff from downspouts/roofs away from wash areas. · Do not locate storm drains in the immediate vicinity of the wash area.
Emergency Storm Drain Seal	· Provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the storm drainage system.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

Purpose

Spills at vehicle and equipment fueling areas can be a significant source of pollution because fuels contain toxic materials and heavy metals that are not easily removed by storm water treatment devices. When storm water mixes with fuel spilled or leaked onto the ground, it becomes contaminated with petroleum-based materials that are harmful to humans, fish and wildlife. This contamination can occur at large industrial sites or at small commercial sites such as gas stations and convenience stores. This fact sheet contains details on specific measures required to prevent or reduce pollutants in stormwater runoff from vehicle and equipment fueling areas, including retail gas stations.

Design Criteria

Design requirements for fueling areas are governed by Building and Fire Codes and by current local agency ordinances and zoning requirements. The design requirements described in this fact sheet are meant to enhance and be consistent with these code and ordinance requirements.

Source Control Design Feature	Design Criteria
Surfacing	· Fuel dispensing areas must be paved with Portland cement concrete. The fuel dispensing area is defined as extending 6.5 feet from the corner of each fuel dispenser or the length at which the hose and nozzle assemble may be operated plus 1 foot, whichever is less. The paving around the fuel dispensing area may exceed the minimum dimensions of the "fuel dispensing area" stated above. · Use asphalt sealant to protect asphalt paved areas surrounding the fueling area.
Covers	· The fuel dispensing area must be covered[1], and the cover's minimum dimensions must be equal to or greater than the area within the grade break or the fuel dispensing area, as defined above. The cover must not drain onto the fuel dispensing area.
Grading/Contouring	· The fuel dispensing area shall have a 2% to 4% slope to prevent ponding and must be separated from the rest of the site by a grade break that prevents run-on of stormwater to the extent practicable. · Grade the fueling area to drain toward a dead-end sump. · Direct runoff from downspouts/roofs away from fueling areas. · Do not locate storm drains in the immediate vicinity of the fueling area.
Emergency Storm Drain Seal	· Provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the storm drainage system.

[1]If fueling large equipment or vehicles that would prohibit the use of covers or roofs, the fueling island should be designed to sufficiently accommodate the larger vehicles and equipment and to prevent run-on and run-off of stormwater. Uncovered fueling areas must be graded to direct stormwater to a dead-end sump.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit.

Purpose

Continued effectiveness of control measures specified in this Plan depends on diligent ongoing inspection and maintenance. To maintain continued effectiveness of control measures, the City may require both a Maintenance Agreement and a Maintenance Plan from the owner/operator of stormwater control measures.

Maintenance Agreement

On-site treatment control measures are to be maintained by the owner/operator. Maintenance agreements between the City and the owner/operator may be required. A Maintenance Agreement with the governing agency must be executed by the owner/operator before occupancy of the project is approved. A sample Maintenance Agreement form is provided in Appendix C.

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the City's request. The Maintenance Plan should address items such as:

- Operation plan and schedule, including a site map;
- Maintenance and cleaning activities and schedule;
- Equipment and resource requirements necessary to operate and maintain facility; and
- Responsible party for operation and maintenance.

Additional guidelines for Maintenance Plans are provided in Appendix D.

SECTION 5

TREATMENT CONTROL MEASURES

Introduction

Treatment control measures, or best management practices (BMPs) are required in addition to source controls to reduce pollution from stormwater discharges to the maximum extent practicable. Treatment control measures are engineered technologies designed to remove pollutants from stormwater runoff. The type of treatment control measure(s) to be implemented at a site depends on a number of factors including: type of pollutants in the stormwater runoff, quantity of stormwater runoff to be treated, project site conditions (e.g. soil type and permeability, slope, etc.), receiving water conditions, and state industrial permit requirements, when applicable. Land requirements, and costs to design, construct and maintain treatment control measures vary by treatment control measure.

Unlike flood control measures that are designed to handle peak flows, stormwater treatment control measures are designed to treat the more frequent, lower-flow storm events, or the first flush portions of runoff from larger storm events (typically referred to as the first-flush events). Small, frequent storm events represent most of the total average annual rainfall for the area. The flow and volume from such small events, referred to as the Stormwater Quality Design Flow (SQDF) and Stormwater Quality Design Volume (SQDV), are targets for treatment. There is marginal water quality benefit gained by sizing treatment facilities to treat flows or volumes larger than the SQDF or SQDV.

The treatment control measures presented in this Plan are designed based on flow rates or volume of runoff. Those designed based on flow are to be designed for the SQDF, and those designed based on volume are to be designed for the SQDV. Definitions and calculation procedures to determine SQDF and SQDV are presented in this Section. The treatment control measures specified in this Plan are to be sized for the SQDF or SQDV only. Flows in excess of SQDF or SQDV are to be diverted around or through the treatment control measure.

The stormwater treatment control measures specified in this section are the more common non-proprietary measures being implemented nationwide. Studies have shown these measures to be reasonably effective if properly installed and maintained. The relative effectiveness of treatment controls specified in this section for removal of pollutants of concern is shown in Table 5-1. Pollutants of concern listed are those that have been identified as causing or contributing to impairment of beneficial uses of water bodies in California. As discussed in Section 2, the measures presented in this Section are preferred and will ensure timely plan check review. Alternative technologies that provide equivalent treatment must be approved by the City on a case by case basis and may result in additional time for City review and approval, unless coordinated in advance with the City staff.

Table 5-1. Efficiency of Treatment Control Measures for Removal of Pollutants of Concern

Treatment Control BMP	Pollutant of Concern[1]			
	Bacteria	Pesticides	Oxygen Demanding Substances	Sediments
Vegetated Buffer Strip	H	M	M	H
Vegetated Swale	M	M	M	M
Extended Detention Basin	H	M	M	H
Wet Pond	H	M	M	H
Constructed Wetland Basin	H	M	M	H
Detention Basin/Sand Filter	H	M	M	H
Porous Pavement Detention Basin	H	M	M	H
Porous Landscape Detention Basin	H	M	M	H
Infiltration Basin	H	M	M	H
Infiltration Trench	H	M	M	H
Media Filter	M	M	M	H
Retention/Irrigation	n/a	n/a	n/a	H
Proprietary Devices[2]	_	_	_	_

[1] H = >75% expected removal efficiency for typical urban stormwater runoff; M = 75% to 25% expected removal efficiency for typical urban stormwater runoff; L = <25% expected removal efficiency for typical urban stormwater runoff.

[2] Effectiveness of proprietary devices varies depending on the manufacturer and type of device. Limited performance data are available.

Unless otherwise agreed to by the City, the landowner, site operator, or homeowner's association is responsible for the operation and maintenance of the treatment control measures. Failure to properly operate and maintain the measures could result in reduced treatment of stormwater runoff or a concentrated loading of pollutants to the storm drain system. To protect against failure, a Maintenance Plan must be developed and implemented for all treatment control measures. Guidelines for maintenance plans are provided in Appendix D of this Plan. The Plan must be made available at the City's request. In addition, a maintenance agreement with the City may be required. The example maintenance agreements are included in Appendix C.

In addition to maintenance, the City may require water quality monitoring agreements for any of the treatment control measures recommended in this Plan. Monitoring may be conducted by the site operator, the City, or both. Monitoring may be required for a period of time to help the City evaluate the effectiveness of treatment control measures in reducing pollutants in stormwater runoff.

Selection of Treatment Controls

Various factors must be considered when selecting a treatment control BMP. In addition to removing target pollutants of concern, site considerations such as the size of the drainage area, depth between the water table and the BMP, soil type and permeability, slope, hydraulic head, size of the BMP, and need for vegetation irrigation are important factors in selecting the proper treatment control BMP. Vector breeding considerations must also be addressed in determining treatment control measures because of nuisance and potential human health effects. The site constraints that are used to select treatment control BMPs are presented in Table 5-2.

Description

This Section provides fact sheets for design and implementation of recommended treatment control measures. The fact sheets include siting, design, and maintenance requirements to ensure optimal performance of the measures. This Plan also contains calculation fact sheets and worksheets to aid in the design of water quality treatment control measures.

Table 5-2. Site Constraints for Treatment Control BMPs[1]

Treatment Control BMP	Drainage Area		Depth to Water Table		Soil Type[2]		Maximum Slope		Hydraulic Head		Vegetation Irrigation		Vector Control Frequency		Maintenance Frequency[3]
	<10 acres	>10 acres	<10 feet	>10 feet	A or B only	A, B, C, or D	~0 %	<15 %	High	Low	Yes	No	High	Low	
Vegetated Buffer Strips	X		X	X	X	X		X		X	X			X	L
Vegetated Swales	X		X	X	X	X		X		X	X			X	L
Extended Detention Basin		X	X	X		X	X			X	X	X	X		M
Wet Pond		X	X	X		X	X			X	X	X	X		M
Constructed Wetland		X	X	X		X	X			X	X		X		H
Detention Basin/Sand Filter		X	X	X		X	X		X			X		X	M
Porous Pavement Detention		X	X	X		X	X		X			X		X	L
Porous Landscape Detention		X	X	X		X	X		X		X			X	L
Infiltration Basin	X			X	X			X	X		X	X		X	H
Infiltration Trench	X			X	X			X	X		X	X		X	L
Media Filter		X	X	X		X	X		X			X		X	H
Retention/Irrigation		X	X	X	X	X		X		X		X	X		L
Proprietary Units[4]															

[1] X indicates BMP is suitable for listed site condition.

[2] Type A soils are sands and gravels with typical infiltration rates of 1.0-8.3 inches/hour. Type B soils are sandy loams with moderately fine to moderately coarse textures and typical infiltration rates of 0.5-1.0 inches/hour. Type C soils are silty-loams or soils with moderately fine to fine texture and typical infiltration rates of 0.17-0.27 inches/hour. Type D soils are clays with infiltration rates of 0.02-0.10 inches/hour.

[3] The maintenance frequency is how often maintenance activities need to be conducted to preserve treatment control BMP effectiveness. H = high; M = medium; L = low.

[4] Suitability of proprietary devices varies depending on the manufacturer and type of device.

Calculation of Stormwater Quality Design Flow and Volume

Introduction

The primary control strategy for all of the treatment control measures specified in this Section is to treat the SQDF or SQDV of the stormwater runoff. The following paragraphs present calculation procedures and design criteria necessary to determine the SQDF and SQDV.

The treatment control measure equations specified in this Section are listed in Table 5-3 along with the basis of design, SQDF or SQDV, to be used for the listed control measure.

Table 5-3. Sizing Criteria for Treatment Control Measures

Treatment Control Measure	Design Basis
T-1: Vegetated Buffer Strip	SQDF
T-2: Vegetated Swale	SQDF
T-3: Extended Detention Basin	SQDV
T-4: Wet Pond	SQDV
T-5: Constructed Wetland	SQDV
T-6: Detention Basin/Sand Filter	SQDV
T-7: Porous Pavement Detention	SQDV
T-8: Porous Landscape Detention	SQDV
T-9: Infiltration Basin	SQDV
T-10: Infiltration Trench	SQDV
T-11: Media Filter	SQDV
T-12: Retention/Irrigation	SQDV
T-13: Proprietary Control Measures	SQDV or SQDF

Contributing Impervious Area Determination

The SQDF and SQDV are calculated by determining runoff from the impervious and pervious areas of a site that are connected to the treatment control measure. Impervious areas include sidewalks, roadways, parking areas, staging areas, storage areas, slabs, roofs, and other non-vegetated areas, including compacted soil areas. Off-site areas that could run-on to a site and contribute drainage to the treatment control measure should be included in the impervious area determination. The effective imperviousness of a site can be reduced through implementation of general site design control measures (e.g. G-4.1 and G-4.2) to reduce flow from impervious areas, as described in Section 3. Procedures for calculating effective imperviousness are presented in Section 3, Fact Sheet G-4.

Stormwater Quality Design Flow (SQDF) Calculation

Hydrologic calculations for design of flow-based stormwater treatment control measures in the Stockton area shall be in accordance with the latest version of the City of Stockton Standard Specifications (Red Book) and the County of San Joaquin Improvement Standards and Hydrology Manual, together with the procedure set forth herein.

The Stormwater Quality Design Flow (SQDF) is defined to be equal to the maximum flow rate of runoff produced by the 85^{th} percentile hourly rainfall intensity, as determined from the local historical rainfall record, multiplied by a factor of two. The 85^{th} percentile hourly rainfall intensity for the Stockton area is estimated to be 0.10 inches/hour, based on cumulative frequency curve for Sacramento presented in the *California Storm Water Best Management Practices Handbook – New Development and Redevelopment,* (2003) for representative rainfall gauges throughout California. The curve for Sacramento is considered representative of rainfall intensities in the Stockton area.

Calculation Procedure

1. Determine the 85^{th} percentile hourly rainfall intensity for the Stockton area. <u>Use 0.10 in/hr.</u>
2. Multiply the 85^{th} percentile hourly rainfall intensity by a factor of two to obtain design rainfall intensity. <u>Use I = 0.10 × 2 = 0.20 in/hr.×</u>
3. Determine the project drainage area and the runoff coefficient "C" for the project drainage area using the procedures set forth in the City standards.
4. Calculate the SQDF

$$SQDF = I \times C \times A = 0.20 \times C \times A$$

Stormwater Quality Design Volume (SQDV) Calculation

Hydrologic calculations for design of volume-based stormwater treatment controls in the Stockton urbanized area shall be in accordance with the procedures set forth herein.

The SQDV is defined as the volume necessary to capture and treat 80 percent or more of the average annual runoff volume from the site at the design drawdown period specified in the Fact Sheet for the proposed treatment control measure.

Calculation Procedure

1. Review the area draining to the proposed treatment control measure. Determine the effective imperviousness (I_{WQ}) of the drainage area using the procedure presented in Section 3, Fact Sheet G-4.
2. Figure 5-1 provides a direct reading of Unit Basin Storage Volumes required for 80% annual capture of runoff for values of "I_{WQ}" determined in Step 1. Enter the horizontal axis of Figure 5-1 with the "I_{WQ}" value from Step 1. Move vertically up Figure 5-1 until the appropriate drawdown period line is intercepted. (The design drawdown period specified in the respective Fact Sheet for the proposed treatment control measure.) Move horizontally across Figure 5-1 from this point until the vertical axis is intercepted. Read the Unit Basin Storage Volume along the vertical axis.

Figure 5-1 is based on rain gauge data from the Sacramento International Airport.

3. The SQDV for the proposed treatment control measure is then calculated by multiplying the Unit Basin Storage Volume by the contributing drainage area. Due to the mixed units that result (e.g., acre-inches, acre-feet), it is recommended that the resulting volume be converted to cubic feet for use during design.

Example Stormwater Quality Design Volume Calculation

1. Determine the drainage area contributing to control measure, A_t. Example: 10 ac
2. Determine the area of impervious surfaces in the drainage area, A_i. Example: 6.4 ac
3. Calculate the percentage of impervious, $I_A = (A_i/A_t) \times 100$

   Example: Percent Imperviousness = $(A_i/A_t) \times 100 = (6.4 \text{ ac}/10 \text{ ac}) \times 100 = 64\%$
4. Determine Effective Imperviousness using Figure 3-4.

   Example: G-4.1 employed → $I_{WQ} = 60\%$
5. Determine design drawdown period for proposed control measure.

   Example: T-3: Extended Detention Basin → Drawdown period = 40 hrs
6. Determine the Unit Basin Storage Volume for 80% Annual Capture, V_u using Figure 5-1.

   Example: for $I_{WQ}/100 = 0.60$ and drawdown = 40 hrs, $V_u = 0.41$ in
7. Calculate the SQDV for the basin, where SQDV = $V_u \times A_t$.

   Example: SQDV = $(0.41 \text{ in}) \times (10 \text{ ac}) \times (\text{ft}/12 \text{ in}) \times (43{,}560 \text{ ft}^2/\text{ac}) = 14{,}883 \text{ ft}^3$
8. Solution: Size the proposed control measure for SQDV = $14{,}883 \text{ ft}^3$ and 40-hr drawdown.

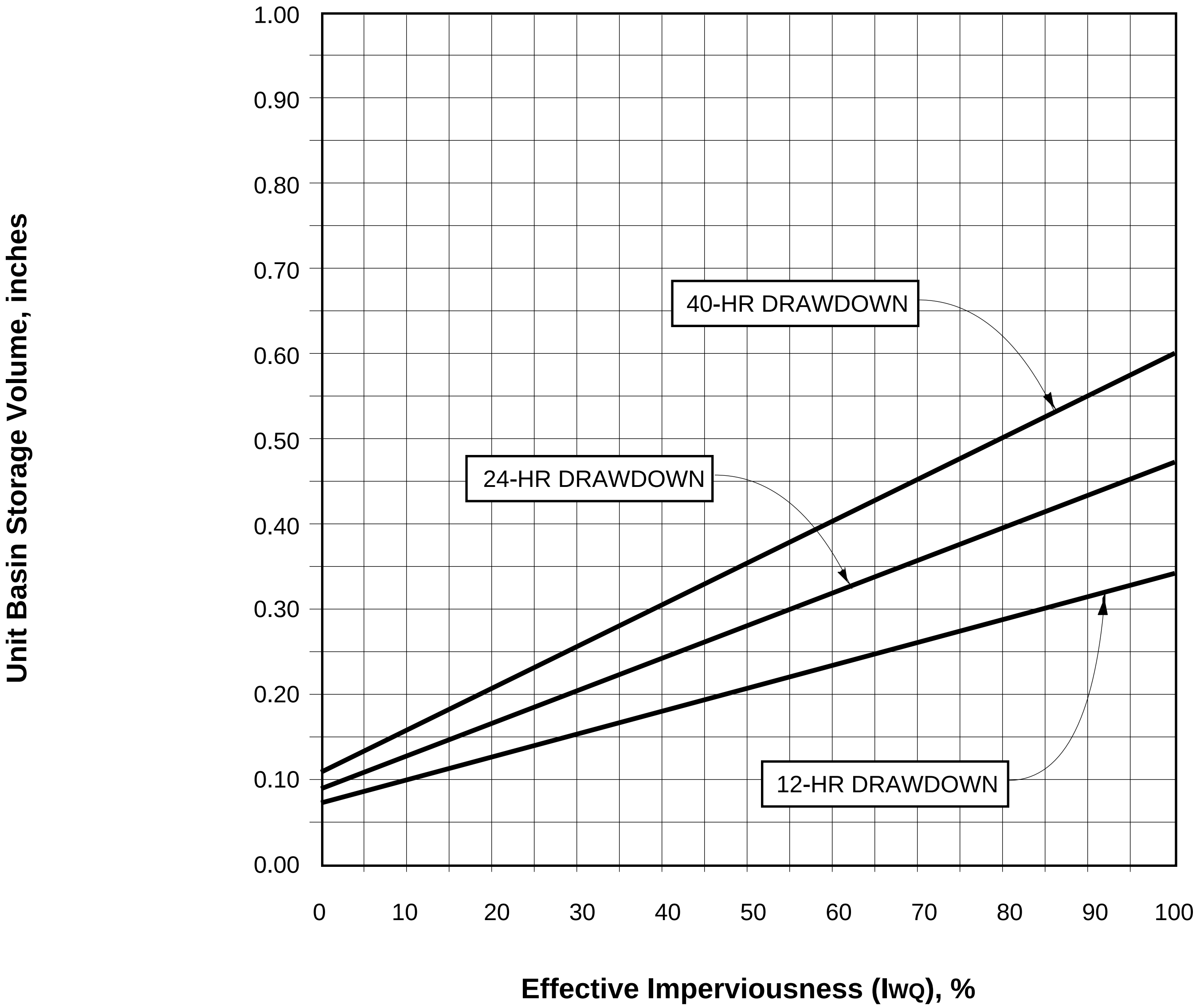


Figure 5-1. Unit Basin Storage Volume vs. Effective Imperviousness

Vegetated Buffer Strip

Description

Vegetated Buffer Strips, or grass strip filters, are uniformly graded vegetated surfaces that are designed to treat sheet flow from adjacent surfaces down the length of the strip. Vegetated buffer strips function by slowing runoff velocities from impervious areas by redistributing the flow evenly across the top of the strip to allow sediment and other pollutants to settle and to provide limited infiltration into the underlying soils. Buffer strips have been used for treatment of agricultural runoff and for treatment of municipal and industrial wastewater (the Overland Flow process), but have recently evolved into urban applications. Buffer strips are sized to treat the SQDF from a tributary area and can provide relatively high pollutant removal, if properly designed and maintained. Additionally, vegetated buffer strips can be aesthetically pleasing. Consequently, the public tends to view them as landscape features, rather than stormwater infrastructure, and the level of public acceptance to their use is typically high.

Vegetated buffer strips are essentially the same as Grass Buffers described in Fact Sheet G-4.1 in Section 3, with the only differences being design criteria for the linear rate of application along top of the strip and the length of strip in the direction of flow. Applications of Vegetated buffer strips are illustrated in Figure 5-2.

General Application

Vegetated buffer strips, appropriate for use in residential, commercial, industrial, and institutional settings, are placed adjacent to the impervious areas to be mitigated and are typically incorporated into the landscape design of the site. Vegetated buffer strips are best suited to treating runoff from roads and highways, roof downspouts, small parking lots, and pervious surfaces. Buffer strips should be located away or protected from excessive pedestrian or vehicular traffic that can damage the grass cover and affect achievement of sheet flow over the surface. Buffer strips are applicable to most regions, but are restricted in some situations because they can use a large amount of space relative to other practices. However, in arid areas the cost of irrigating the vegetation may outweigh its water quality benefits.

Tributary areas to vegetated buffer strips are typically less than five acres. Several vegetated buffer strips may be used together for larger sites. The use of buffer strips is limited to gently sloping areas where full vegetative cover can be maintained and where shallow flow characteristics are possible. Slopes should not exceed four (4) percent or be less than one (1) percent. Using a level spreading device to facilitate overland sheet flow is not usually recommended because of maintenance and vector control considerations. Buffer strips should be separated from the groundwater table by at least two to four feet to prevent contamination and to ensure that the buffer strip does not remain wet between storms. To limit the size of units when space is limited, runoff flow from pervious off-site areas should not be routed over buffer strips.

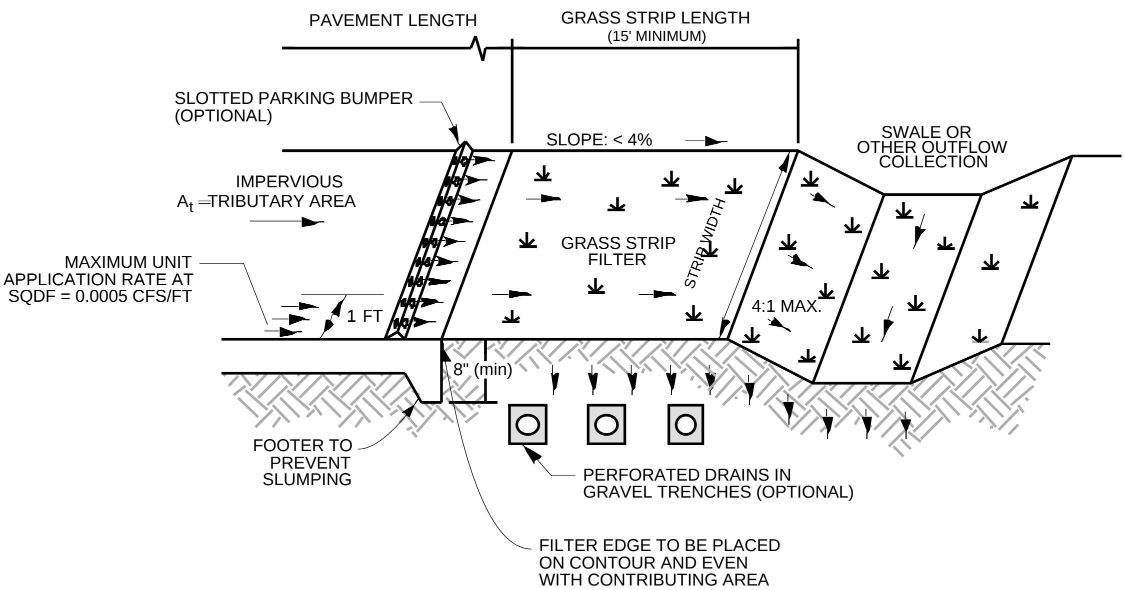
Buffer strips are not expected to increase stormwater runoff temperatures. As a result, buffer strips are effective for protection of cold-water stream habitat in which temperature variation is a concern.

Advantages

- Vegetated buffer strips can provide reliable water quality benefits and high aesthetic appeal.
- Flow characteristics and vegetation type and density can be controlled to maximize effectiveness.
- Roadside shoulders are effective sites for buffer strips if slope and length criteria are met.
- Vegetated buffer strips are relatively easy to design, install, and maintain.
- In addition to pollutant removal, vegetated buffer strips provide opportunities for infiltration of runoff, which can reduce peak flows.

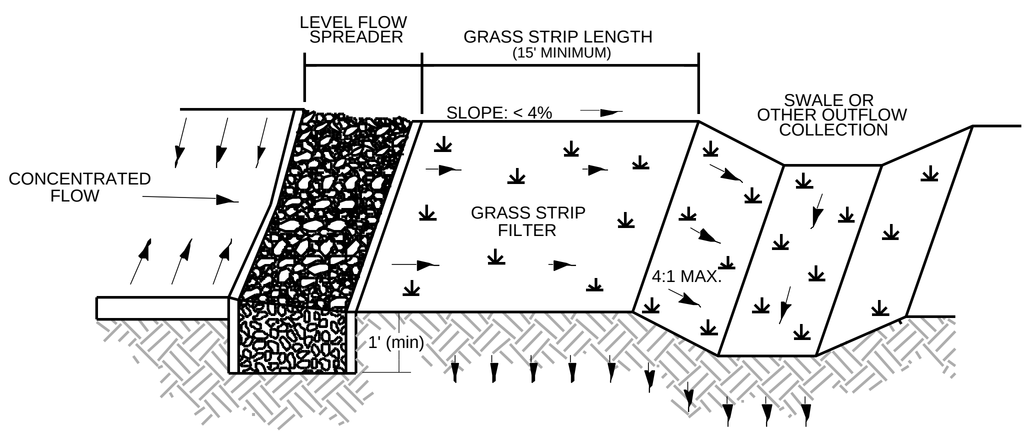
Disadvantages

- Vegetated buffer strips may not be appropriate for industrial sites where spills may occur.
- Vegetated buffer strips are limited to drainage areas less than approximately five (5) acres.
- Buffer strips are not effective in removing dissolved constituents except for incidental infiltration.



SHEET FLOW CONTROL

NOT TO SCALE



CONCENTRATED FLOW CONTROL

NOT TO SCALE

Figure 5-2 VEGETATED BUFFER STRIP

ADAPTED FROM URBAN STORM DRAIN CRITERIA MANUAL VOL. 3 - BEST MANAGEMENT PRACTICES, URBAN DRAINAGE AND FLOOD CONTROL DISTRICT,11/99

Performance

Relative pollutant removal effectiveness of vegetated buffer strips is presented in Table 5-1. Vegetated buffer strips provide somewhat better treatment of stormwater runoff than swales and have fewer tendencies for channelization or erosion. Removal effectiveness of buffer strips for sediment and particulate forms of metals, nutrients, and other pollutants is considered high to moderate. Vegetated buffer strips also exhibit good removal of litter and other floatables because water depth in these systems is below the vegetation height, which results in difficulty for these materials to be transported. However, buffer strips have limited removal efficiencies for dissolved constituents. Vegetated buffer strips are particularly effective when used as an upstream control measure in combination with vegetated swales, sand filters, and infiltration control measures.

Design Criteria and Procedure

Principal design criteria for vegetated buffer strips are listed in Table 5-4.

Table 5-4. Vegetated Buffer Strips Design Criteria

Design Parameter	Unit	Design Criteria
Design Flow (SQDF)	cfs	0.20 × C × Area
Maximum linear unit application rate (q_a)	cfs/ft _ width	0.005
Minimum width (normal to flow) (W_{VBS})	ft	(SQDF)/(q_a)
Minimum length (flow direction) (L_{VBS})	ft	15
Maximum slope (flow direction)	%	4
Vegetation	–	Turf grass (irrigated) or approved equal
Minimum grass height	in	2
Maximum grass height	in	4 (typical) or as required to prevent lodging or shading

Design procedure and application of design criteria are outlined in the following steps:

1. Design Flow — Determine SQDF for impervious area to be mitigated.

   $$SQDF = 0.20 \times C \times Area$$

2. Minimum Width — Calculate minimum width of the Vegetated Buffer Strips (W_{VBS}) normal to flow direction.

   $$W_{VBS} = (SQDF)/(q_a)$$

   $$W_{VBS} = (SQDF)/0.005 \text{ cfs/ft (minimum)}$$

3. Minimum Length — Length of the Vegetated Buffer Strips (L_{VBS}) in the direction of flow shall not be less than 15 feet.

   $$L_{VBS} = 15 \text{ ft (minimum)}$$

4. Maximum Slope — Slope of the ground in the direction of flow shall not be greater than 4 percent.

5.	Flow Distribution	Incorporate a device at the upstream end of the Vegetated Buffer Strips to evenly distribute flows along the top width, such as slotted curbing, modular block porous pavement, or other spreader devices. Concentrated flow delivered to the vegetated buffer strips must distributed evenly by means of a level spreader of similar concept.
6.	Vegetation	Provide irrigated perennial turf grass to yield full, dense cover. (See Appendix F for suitable grasses). Submit a Landscape Plan for City stormwater staff review. Plan shall be prepared by a landscape or other appropriate specialist and shall include a site plan showing location and type of vegetation. Mow grass to maintain height approximately between 2 and 4 inches.
7.	Outflow Collection	Provide a means for outflow collection and conveyance (e.g. grass channel/swale, storm sewer, street gutter).

Design Example

A completed design form follows as a design example. Blank design forms are provided in Appendix G.

Design Procedure Form for T-1: Vegetated Buffer Strips

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Design Flow	SQDF = 0.5 cfs
2. Design Width W_{VBS} = (SQDF)/0.005 cfs/ft	W_{VBS} = 100.0 ft
3. Design Length (15 ft min.)	L_{VBS} = 15.0 ft
4. Design Slope (4% max.)	S_{VBS} = 3.0 %
5. Flow Distribution (Check type used or describe “Other”)	X Slotted curbing _____ Modular Block Porous Pavement _____ Level Spreader _____ Other ________________
6. Vegetation (describe)	Tall Fescue
7. Outflow Collection (Check type used or describe “Other”)	_____ Grass Swale X Street Gutter _____ Storm Sewer _____ Underdrain Used _____ Other ________________

Notes ____

Construction Considerations

Scheduling

Vegetated buffer strips should be established and operational by October 1, unless another schedule has been justified in the Landscape Plan and approved by the City. To meet the October 1 deadline, the following schedule must be met:

- Seeding should be conducted during the dry season, no later than September 1 to ensure sufficient vegetation by October 1. Irrigation may be required.
- Within 60 days of seeding, or by September 30, whichever is earlier, the site shall be inspected to determine adequacy of vegetation growth, and to determine if erosion or damage has occurred. Areas of damage shall be repaired, seeded, and mulched immediately.
- If vegetation growth is insufficient, or excessive damage or erosion has occurred, the site will be further stabilized with other appropriate erosion control measures such as matting, mulching, etc. If the site cannot be adequately stabilized prior to October 1, temporary measures must be installed to divert storm flows around the vegetated buffer strips until adequate vegetation and stabilization occurs.

During Construction

If active construction is being conducted upstream of the vegetated buffer strips, all construction activity BMPs must remain in place to prevent high sediment loads into the vegetated buffer strips. If necessary additional BMPs must be installed to protect the vegetated buffer strips during construction.

Post Construction

After all construction activities are complete, necessary temporary BMPs to protect the integrity of the vegetated buffer strips shall be installed, if necessary, until:

- the drainage area for the vegetated buffer strips is adequately stabilized;
- vegetation in the vegetated buffer strips is adequately established; and
- the vegetated buffer strips maintenance plan is fully implemented.

Maintenance Requirements

To provide optimum treatment, vegetated buffer strips need to be regularly maintained to ensure a dense vegetation growth, and to prevent erosion of the underlying soils.

Maintenance Agreement

Treatment controls are to be maintained by the owner/operator. Maintenance agreement between the owner/operator of the vegetated buffer strips and the City may be required (See Appendix C for example maintenance agreement).

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the City's request. The Maintenance Plan should address at least the following items (see Appendix D for more detailed suggested Maintenance Plan content and format):

- Operation plan and schedule, including site map;
- Maintenance and cleaning activities and schedule;
- Equipment and resource requirements necessary to operate and maintain facility; and
- Responsible party for operation and maintenance activities.

Maintenance Activities

The following activities are recommended to properly maintain vegetated Buffer Strips:

- Mow regularly to maintain vegetation height between two and four inches and to promote thick, dense vegetative growth. Mowing may only be necessary once or twice a year for safety and aesthetics or to suppress weeds and woody vegetation.
- Remove all litter, branches, rocks, or other debris. Remove all accumulated sediment that may obstruct flow.
- Damaged areas of the buffer strip should be repaired immediately by reseeding and applying mulch.
- Regularly maintain inlet flow spreader, if applicable.
- Irrigate buffer strips during dry season, if necessary, to maintain the vegetation.
- Once the buffer strip is established, inspect for erosion or damaged vegetation at twice three times per year. Inspections should occur preferably at the end of the wet season to schedule summer maintenance and before major fall runoff to be sure that the strip is ready for winter.
- Regularly inspect the buffer strips for pools of standing water to prevent mosquito breeding, particularly at inlet flow spreaders and in places where obstructions develop.

Vegetated Swale

Description

Vegetated swales, or grass swale filters, are densely vegetated open, shallow channels with gentle side slopes and slopes in the direction of flow that collect and slowly convey runoff to downstream points of discharge. A vegetated swale is sized to treat the SQDF from the tributary area. They are designed to treat runoff by filtering through the vegetation in the channel, filtering through a subsoil matrix, and/or infiltration into the underlying soil. Swales trap particulate pollutants, promote infiltration, and reduced the flow velocity of stormwater runoff. Vegetated swales can serve as part of a stormwater drainage system and can replace curbs, gutters, and storm sewer systems.

Vegetated swales are similar to Grass-lined Channels described in Fact Sheet G-4.2 in Section 3, with the only differences being design criteria for hydraulic design parameters (e.g. flow depth, friction factor, and contact time.) Vegetated swales require shallower flow depths and longer contact times to provide treatment. Applications of vegetated swales are illustrated in Figure 5-3.

General Application

Vegetated swales, appropriate for use in residential, commercial, industrial, and institutional settings, are placed adjacent to the impervious areas to be mitigated and are typically incorporated into the landscape design of the site. The suitability of vegetated swales at a site depends on land use, size and imperviousness of the tributary area, soil type, size and slope of the swale system, and availability of water during the dry season. Site topography may also dictate a need for additional structural controls. Vegetated swales are often used in conjunction with vegetated buffer strips to provide runoff collection and conveyance as well as treatment.

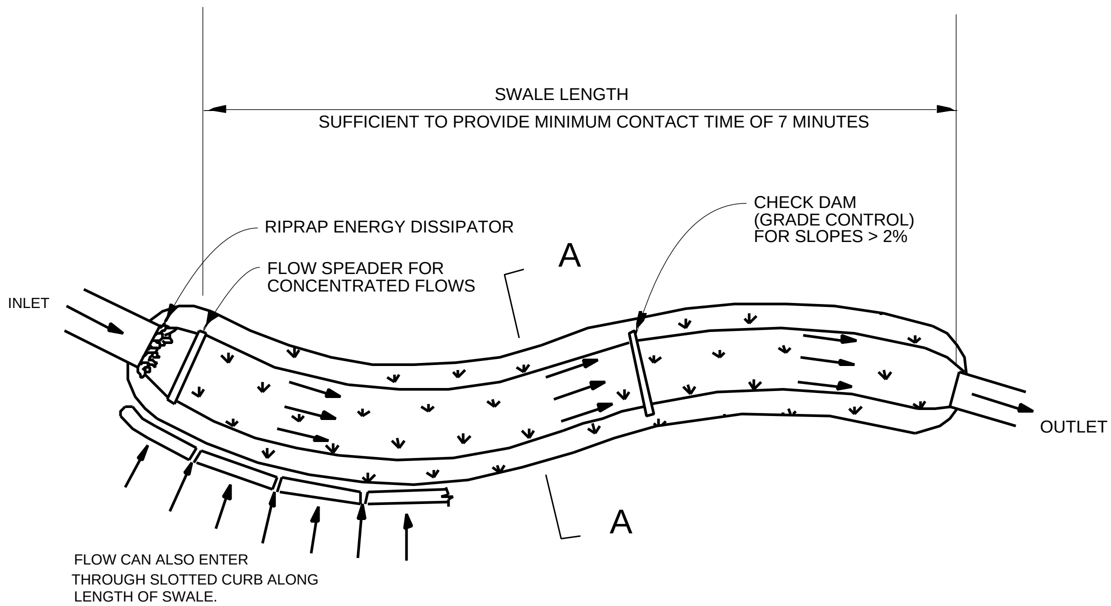
Tributary areas are typically less than 10 acres and several vegetated swales may be used together for larger sites. Vegetated swales are not practical for sites with slopes greater than about five percent. Berms or check dams may be installed perpendicular to flow to provide grade control in steeper sloped areas. The use of check dams with swales also promotes infiltration, which can lead to higher pollutant removal effectiveness. Underdrains are recommended for design slopes less than 0.5 percent when soils types C or D are present. Runoff flow from pervious off-site areas should not be routed over vegetated swales in order to limit the size of units, if space is limited.

Advantages

- Vegetated swales can serve as an aesthetic, potentially inexpensive urban development or roadway drainage conveyance measure with significant water quality benefits.
- Roadside shoulders are effective sites for swales.
- Vegetated swales are relatively easy to design, install, and maintain.
- In addition to pollutant removal, swales provide opportunities for infiltration of runoff, which can reduce peak flows.

Disadvantages

- Vegetated swales may not be appropriate for industrial sites where spills may occur.
- Swales cannot treat a very large drainage area.
- A thick vegetative cover is needed for these practices to function properly.
- Swales are impractical in areas with steep topography.
- Swales are not effective and may even erode, causing channelization, when flow velocities are high or when the cover is not properly maintained.
- In some places, their use is restricted by law because many local municipalities require curb and gutter systems in residential areas.



TRAPEZOIDAL GRASS SWALE PLAN

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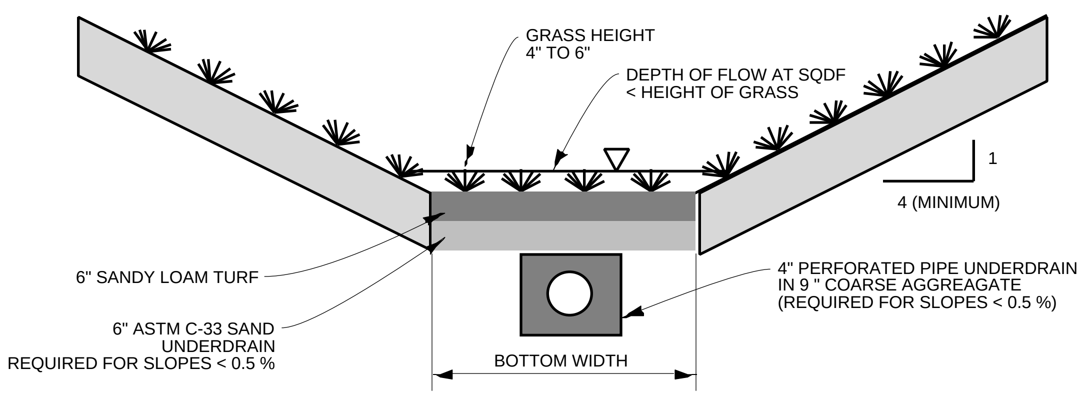


TRAPEZOIDAL GRASS SWALE SECTION

NOT TO SCALE

ADAPTED FROM URBAN STORM DRAIN CRITERIA MANUAL
VOL. 3 - BEST MANAGEMENT PRACTICES,
URBAN DRAINAGE AND FLOOD CONTROL DISTRICT,11/99

Figure 5-3 VEGETATED SWALE

Performance

Relative pollutant removal effectiveness of vegetated swales is presented in Table 5-1. The literature suggests that vegetated swales represent a practical and potentially effective technique for controlling urban runoff quality. Check dams, slight slopes, permeable soils, dense grass cover, increased contact time, and small storm events all contribute to successful pollutant removal by the swale system. Additionally, incorporating vegetated buffer strips parallel to the top of the channel banks can help to treat sheet flows entering the swale. Factors decreasing the effectiveness of swales are compacted soils, short runoff contact time, large storm events, frozen ground, short grass heights, steep slopes, and high runoff velocities and discharge rates.

Removal effectiveness of vegetated swales for sediment and particulate forms of metals, nutrients, and other pollutants is considered moderate to low. Swales tend to export bacteria and phosphorus. Vegetated swales are the least effective of the approved treatment control measures and should generally be used in conjunction with other approved treatment control measures.

Design Criteria and Procedure

Principal design criteria for vegetated swales are listed in Table 5-5.

Table 5-5. Vegetated Swales Design Criteria

Design Parameter	Unit	Design Criteria
Design Flow (SQDF)	cfs	0.20 ×C × Area
Swale geometry	–	Trapezoidal or triangular
Maximum channel side slope	H:V	4 :1
Minimum slope in flow direction	%	0.2 (provide underdrains for slopes < 0.5)
Maximum slope in flow direction	%	2.0 (provide grade-control checks for slopes >2.0)
Maximum flow velocity	ft/sec	1.0 (based on Manning n = 0.20)
Maximum depth of flow at SQDF	in	3 to 5 (1 in below top of grass)
Minimum contact time	min	10 (provide sufficient length to yield min contact time)
Minimum length	ft	Sufficient length to provide minimum contact time
Vegetation	–	Turf grass or approved equal
Grass height	in	4 to 6 (mow to maintain height)

Design procedure and application of design criteria are outlined in the following steps:

1. Design Flow	Determine SQDF for impervious area to be mitigated. $$SQDF = 0.20 \times C \times Area$$
2. Swale Geometry	Use trapezoidal or triangular cross section.
3. Maximum Side Slope	Side slops shall not be steeper than 4:1 (5:1 or flatter preferred).
4. Minimum Slope	Slope of the swale in the direction of flow shall not be less than 0.2 percent. Swales with slopes less than 0.5 percent should be provided with underdrains (see Figure 5-3).
5. Maximum Slope	Slope of the swale in the direction of flow shall not be greater than 2 percent. Provide grade control checks for slopes greater than 2.0 percent (see Figure 5-3).
6. Flow Velocity	Maximum flow velocity at design flow should not exceed 1.0 ft/sec based on a Manning's n = 0.20.
7. Flow Depth	Maximum depth of flow at design flow should not exceed 3 to 5 inches based on a Manning's n = 0.20.
8. Swale Length	Provide length in the flow direction sufficient to yield a minimum contact time of 10 min at SQDF or 100 ft, whichever is greater
9. Vegetation	Provide irrigated perennial turf grass to yield full, dense cover (See Appendix F for suitable grasses). Mow to maintain height of 4 to 6 in.
10. Drainage & Flood Control	Provide sufficient flow depth for flood event flows to avoid flooding of critical areas or structures.

Design Example

A completed design form follows as a design example. Blank design forms are provided in Appendix G.

Design Procedure Form for T-2: Vegetated Swales

Designer:________________________________

Company:________________________________

Date:________________________________

Project:________________________________

Location:________________________________

1. Design Flow	SQDF = 1.0 cfs
2. Swale Geometry a. Swale Bottom Width (b) b. Side slope (Z)	b = 10.0 ft Z = 4:1
3. Depth of flow at SQDF (d) (2 ft max., Manning n= 0.20)	d = 5.0 in
4. Design Slope a. s = 4% max. b. No. of grade controls required	s = 0.26 % 0 (number)
5. Design flow velocity (Manning n= 0.20)	V = 0.21 ft/sec
6. Design Length L = (10 min) _ (flow velocity, ft/sec) _ 60, or 100 ft	L = 126.0 ft
6. Vegetation (describe)	Tall Fescue
7. Outflow Collection (Check type used or describe "Other")	X Grated Inlet _____ Infiltration Trench _____ Underdrain Used _____ Other ________________

Notes ________________________________

Construction Considerations

Scheduling

Vegetated swales should be established and operational by October 1, unless another schedule has been justified in the Landscape Plan and approved by the City. To meet the October 1 deadline, the following schedule must be met:

- Seeding should be conducted during the dry season, no later than September 1 to ensure sufficient vegetation by October 1. Irrigation may be required.
- Within 60 days of seeding, or by September 30, whichever is earlier, the site shall be inspected to determine adequacy of vegetation growth, and to determine if erosion or damage has occurred. Areas of damage shall be repaired, seeded, and mulched immediately.
- If vegetation growth is insufficient, or excessive damage or erosion has occurred, the site should be further stabilized with other appropriate erosion control measures such as matting, mulching, etc. If the site can not be adequately stabilized prior to October 1, temporary measures must be installed to divert storm flows around the swale until adequate vegetation and stabilization occurs.

During Construction

If active construction is being conducted upstream of the vegetated swales, all construction activity BMPs must remain in place to prevent high sediment loads into the vegetated swales. If necessary, additional BMPs must be installed to protect the vegetated swales during construction.

Post Construction

After all construction activities are complete, temporary BMPs to protect the integrity of the vegetated swales shall be installed, if necessary, until:

- the drainage area for the vegetated swales is adequately stabilized;
- vegetation in the vegetated swales is adequately established; and
- the vegetated swales maintenance plan is fully implemented.

Maintenance Requirements

To provide optimum treatment, vegetated swales need to be regularly maintained to ensure a dense vegetation growth, and to prevent erosion of the underlying soils.

Maintenance Agreement

Treatment controls are to be maintained by the owner/operator. Maintenance agreement between the owner/operator of the vegetated swales and the City may be required. (See Appendix C for example maintenance agreement.)

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the City’s request. The Maintenance Plan should address at least the following items (see Appendix D for more detailed suggested Maintenance Plan content and format:

- Operation plan and schedule, including site map;

- Maintenance and cleaning activities and schedule;
- Equipment and resource requirements necessary to operate and maintain facility; and
- Responsible party for operation and maintenance activities.

Maintenance Activities

The following activities are recommended to properly maintain vegetated swales:

- Inspect swales at least twice annually for erosion, damage to vegetation, and sediment and debris accumulation, preferably at the end of the wet season to schedule summer maintenance and before major fall runoff to be sure the swale is ready for winter. However, additional inspection after periods of heavy runoff is desirable. Remove damaged vegetation, sediment, and trash and debris.
- Swale height and mowing frequency may not have a large impact on pollutant removal, but mowing may only be necessary once or twice a year for safety, aesthetics, or suppression weeds and woody vegetation. Additionally, mowing promotes dense swale growth.
- Regularly inspect swales for pools of standing water to prevent mosquito breeding, particularly in places were obstructions develop.
- Irrigate vegetated swale during dry season, if necessary, to maintain vegetation.

Description

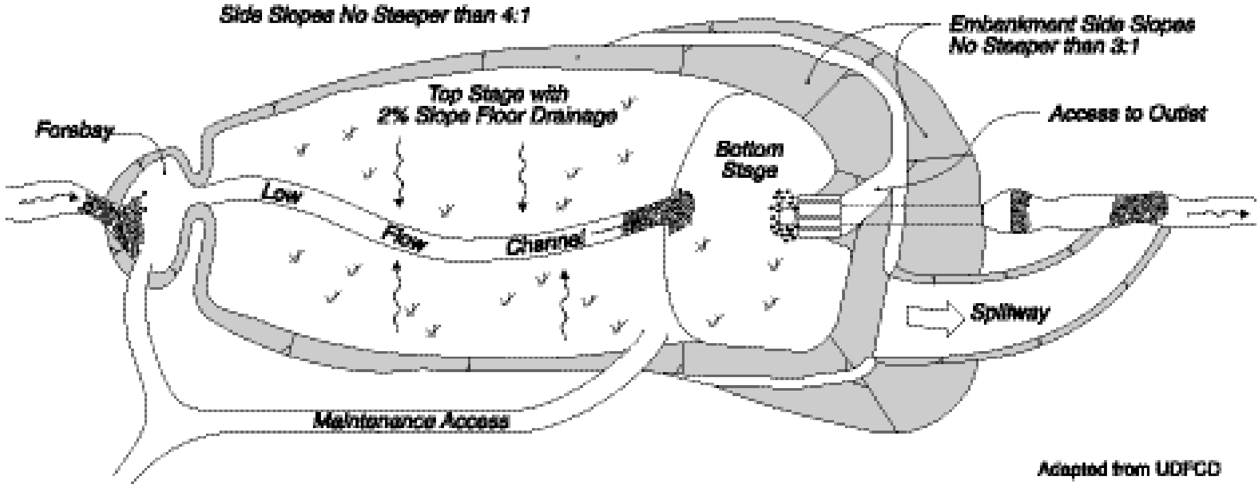
Extended detention basins are permanent basins formed by excavation and/or construction of embankments to temporarily detain the SQDV of stormwater runoff to allow for the sedimentation of particulates to occur before the runoff is discharged. An extended detention basin serves to reduce peak stormwater runoff rates, as well as provide treatment of stormwater runoff. Extended detention basins are typically dry between storms, although a shallow pool, one to three feet deep, can be included in the design for aesthetic purposes and to promote biological uptake and conversion of pollutants. A bottom outlet provides a controlled slow release of the detained runoff over a specified time period. Extended detention basins can also be used to provide flood control by including additional detention storage. The basic elements of an extended detention basin are shown in Figure 5-4. This configuration is most appropriate for large sites.

General Application

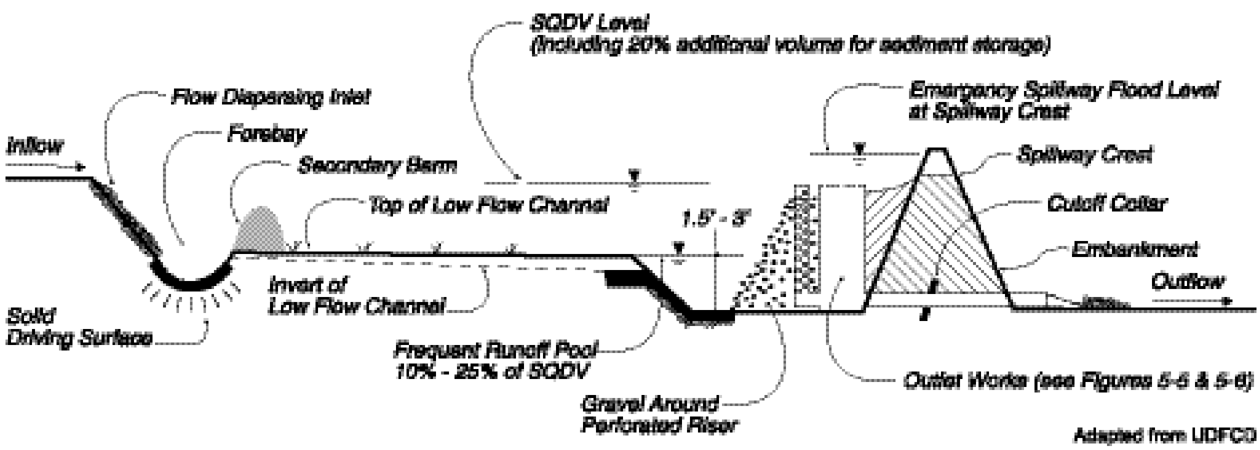
Extended detention basins are among the most widely applied stormwater treatment control measures and are especially useful in retrofit situations where their low hydraulic head requirements allow them to be sited within the constraints of the existing storm drain system. Basins may be designed as dual-use facilities to provide recreational use during the dry season and can be designed into flood control basins or sometimes retrofitted into existing flood control basins. Surface basins are typical, but underground vaults may be appropriate in a small commercial development. If the basins are constructed early in the land development cycle, they can serve as sediment traps during construction within the tributary area.

Extended detention basins can serve essentially any size tributary area from an individual commercial development to a large residential or regional area, but are typically used for tributary areas greater than five acres. Land requirements for the basins range from approximately 0.5 to 2 percent of the tributary development area. The bottom of the basin is sloped toward the outlet end at a grade of approximately two percent. Basins can be used with almost all soils and geology, with minor adjustments for regions with rapidly percolating soils. In these areas, impermeable liners can be installed to prevent groundwater contamination. The base of the basin should not intersect the groundwater table because a permanently wet bottom can become a vector breeding ground.

Studies have found that extended detention basins can increase water temperatures. Consequently, the temperature impact of detention basin discharges to cold water receiving waters must be considered.



Plan View



Section View

Figure 5-4. Extended Detention Basin Conceptual Layout

Advantages

- Extended detention basins may be designed to provide other benefits such as recreation, wildlife habitat, and open space. Safety issues must be addressed.
- Basins are relatively easy and inexpensive to build and operate due to its simple design.
- Extended detention basins can provide substantial capture of sediment and pollutants associated with particulates.
- Widespread application with sufficient capture volume can provide significant control of channel erosion and enlargement caused by changes to stormwater flow.

Disadvantages

- Dry extended detention basins provide moderate pollutant removal when compared to some other structural stormwater practices and are relatively ineffective at removing soluble pollutants.
- Although wet detention basins can increase property values, dry ponds can adversely affect the value of nearby property due to the adverse aesthetics of dry, bare areas and inlet and outlet structures.

Performance

Relative pollutant removal effectiveness of an EDB is presented in Table 5-1. Removal effectiveness of extended detention basins for sediment and particulate forms of metals, nutrients, and other pollutants is considered high to moderate. Removal effectiveness for dissolved pollutants is considered low. The mass reduction is greater than the concentration reduction because of the substantial infiltration that occurs. Although the infiltration of stormwater is clearly beneficial to surface receiving waters, there is the potential for groundwater contamination. Vegetated basins will not only mitigate erosion, but also appear to have greater pollutant removal than non-vegetated or concrete basins due to stabilization of captured sediment. These basins may be used upstream of control measures that are more effective at removing soluble pollutants.

Design Criteria and Procedure

Principal design criteria for extended detention basins are listed in Table 5-6.

Table 5-6. Extended Detention Basin Design Criteria

Design Parameter	Unit	Design Criteria
Drawdown time for SQDV/50% SQDV	hrs	40/12 (minimum)
SQDV	ac-ft	80% annual capture. Use Figure 5-1 @ 40-hr drawdown
Basin design volume	ac-ft	1.2 × SQDV (provide 20% sediment storage volume)
Inlet/outlet erosion control	–	Energy dissipater to reduce inlet/outlet velocity
Forebay volume/drain time	%/min	5-15% of SQDV/Drain time < 15 min @ 15%
Low-flow channel depth/flow capacity	in / –	9 / 2 × forebay outlet rate

Design Parameter	Unit	Design Criteria
Bottom slope of upper stage	%	2.0
Length to width ratio (minimum)	–	2:1 (larger preferred)
Upper stage depth/width (minimum)	ft	2.0/30
Bottom stage volume	%	10-25% of SQDV
Bottom stage depth	ft	1.5-3 ft deeper than top stage
Freeboard (minimum)	ft	1.0
Embankment side slope (H:V)	H:V	≥ 4:1 inside/ ≥3:1 outside (without retaining walls)
Maintenance access ramp slope (H:V)	H:V	10:1 or flatter
Maintenance access ramp width	ft	16.0 – approach paved with asphalt concrete

Design procedure and application of design criteria are outlined in the following steps:

1. Basin Storage Volume — Provide a storage volume equal to 120 percent of the SQDV, based on a 40-hr drawdown time, above the lowest outlet (i.e. perforation or orifice) in the basin. The additional 20 percent provides an allowance for sediment accumulation.

   a. Determine the percent imperviousness of the tributary area (I_a).

   b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate.

   c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 40-hr drawdown and I_{wq} value from Step 1.b.

   d. Calculate the SQDV (ac-ft) as follows:

   $$SQDV = (V_u/12) \times Area$$

   where

   Area = Watershed area tributary to extended detention basin (ac)

   e. Calculate Design Volume in acre-ft as follows:

   $$Design\ Volume = SQDV \times 1.2$$

   where

   1.2 = Multiplier to provide for sediment accumulation

2. Outlet Works — The Outlet Works are to be designed to release the SQDV (i.e. not Design Volume) over a 40-hour period, with no more than 50 percent released in 12 hours. Refer to Figures 5-5 and 5-6 for schematics pertaining to structure geometry; grates, trash racks,

and screens; outlet type: orifice plate or perforated riser pipe.

a. For perforated pipe outlets or vertical plates with multiple orifices (see Figure 5-5), use the following equation to determine required area per row of perforations, based on the SQDV (acre-ft) and depth of water above the centerline of the bottom perforation D_{BS} (ft).

$$\text{Area/row (in}^2) = SQDV/K_{40}$$

where

$$K_{40} = 0.013D_{BS}^2 + 0.22D_{BS} - 0.10$$

Select appropriate perforation diameter and number of perforations per row (i.e. columns) with the objective of minimizing the number of columns and using a maximum perforation diameter of 2 inches. Rows are spaced at 4 inches on center from the bottom perforation. Thus, there will be 3 rows for each foot of depth plus the top row. The number of rows (nr) may be determined as follows:

$$nr = 1 + (D_{BS} \times 3)$$

Calculate total outlet area by multiplying the area per row by number of rows.

$$\text{Total Orifice Area} = \text{area/row} \times nr$$

b. For single orifice outlet control or single row of orifices at the basin bottom surface elevation (see Figures 5-6), use the following equation based on the SQDV (ft^3) and depth of water above orifice centerline D_{BS} (ft) to determine total orifice area (in^2):

$$\text{Total Orifice Area} = (SQDV) \div [(60.19)(D_{BS}^{0.5})(T)]$$

where

T = drawdown period (hrs) = 40 hrs

3. Trash Rack/Gravel Pack — A trash rack or gravel pack around perforated risers shall be provided to protect outlet orifices from clogging. Trash racks are better suited for use with perforated vertical plates for outlet control and allow easier access to outlet orifices for purposes of inspection and cleaning. Trash rack shall be sized to prevent clogging of the primary water quality outlet without restricting with the hydraulic capacity of the outlet control orifices.

4. Basin Shape — Whenever possible, shape the basin with a gradual expansion from the inlet toward the middle and a gradual contraction from middle toward the outlet. The length to width ratio should be a minimum of 2:1. Internal baffling with berms may be necessary to achieve this ratio.

5. Two-Stage Design	A two-stage design with a pool that fills often with frequently occurring runoff minimizes standing water and sediment deposition in the remainder of the basin. a. Upper Stage: The upper stage should be a minimum of 2 feet deep with the bottom sloped at 2 percent toward the low flow channel. Minimum width of the upper stage should be 30 feet. b. Bottom Stage: The active storage basin of the bottom stage should be 1.5 to 3 feet deeper than the top stage and store 10 to 25 percent of the SQDV. A micro-pool below the active storage volume of the bottom stage, if provided, should be one-half the depth of the top stage or 2 feet, whichever is greater.
6. Forebay Design	The forebay provides a location for sedimentation of larger particles and has a solid bottom surface to facilitate mechanical removal of accumulated sediment. The forebay volume should be 5 to 10 percent of the SQDV. A berm should separate the forebay from the upper stage of the basin. The outlet pipe from the forebay to the low-flow channel should be sized to drain the forebay volume in 45 minutes. The outlet pipe entrance should be offset from the forebay inlet to prevent short-circuiting.
7. Low-flow Channel	The low-flow channel conveys flow from the forebay to the bottom stage. Erosion protection should be provided where the low-flow channel enters the bottom stage. Lining of the low flow channel with concrete is recommended. The depth of the channel should be at least 9 inches. The flow capacity of the channel should be twice the release capacity of the forebay outlet.
8. Inlet/Outlet Design	Basin inlet and outlet points should be provided with an energy dissipation structure and/or erosion protection.
9. Vegetation	Bottom vegetation provides erosion protection and sediment entrapment. Basin bottoms, berms, and side slopes may be planted with native grasses or with irrigated turf.
10. Embankment	Design embankments to conform to State of California Division of Safety of Dams requirements, if the basin dimensions cause it to fall under that agency's jurisdiction. Interior slopes should be no steeper than 4:1 and exterior slopes no steeper than 3:1. Flatter slopes are preferable.
11. Access	All-weather access to the bottom, forebay, and outlet works shall be provided for maintenance vehicles. Maximum grades of access ramps should be 10 percent and minimum width should be 16 feet. Ramps should be paved with concrete.
12. Bypass	Provide for bypass or overflow of runoff volumes in excess of

	the SQDV. Spillway and overflow structures should be designed in accordance with applicable standards of the City.
13. Geotextile Fabric	Non-woven geotextile fabric used in conjunction with gravel packs around perforated risers shall conform to the specifications listed in Table 5-7.

Table 5-7. Non-woven Geotextile Fabric Specifications

Property	Test Reference	Minimum Specification
Grab Strength	ASTM D4632	90 lbs
Elongation at peak load	ASTM D4632	50%
Puncture Strength	ASTM D3787	45 lbs
Permitivity	ASTM D4491	0.7 sec^{-1}
Burst Strength	ASTM D3786	180 psi
Toughness	% Elongation _ Grab Strength	5,500 lbs
Ultraviolet Resistance (Percent strength retained at 500 Weatherometer hours)	ASTM D4355	70%

Adapted from SSPWC, 1997.

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-3: Extended Detention Basin (Page 1 of 2)

Designer:____________________

Company:____________________

Date:____________________

Project:____________________

Location:____________________

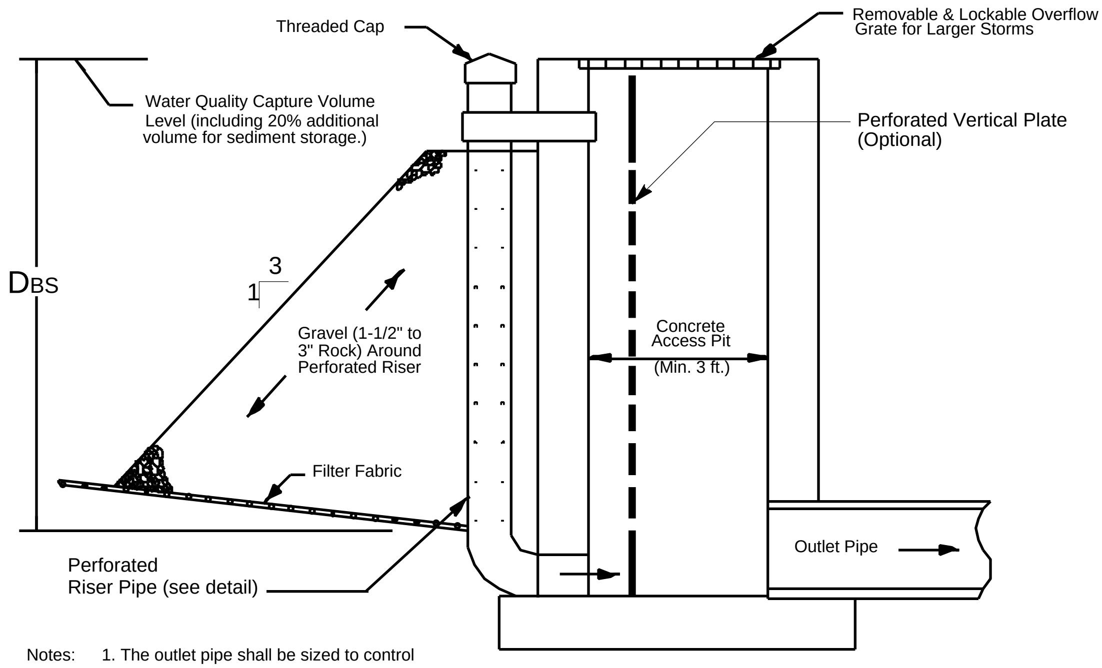
1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	64	%
b. Effective Imperviousness (Determine using Figure 3-4)	I_{wq} =	60	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40-hr drawdown and I_{wq}	V_u=	0.41	in
d. Watershed Area Tributary to EDB	Area =	10	ac
e. Calculate SQDV SQDV = (V_u/12) × Area	SQDV =	0.34	ac-ft
f. Calculate Design Volume Design Volume = SQDV × 1.2	Design Volume =	0.41	ac-ft
2. Outlet Works			
a. Outlet Type (check one)	Single Orifice	X	
	Multi-orifice Plate		
	Perforated Pipe		
	Other		
b. Depth of water above bottom orifice	Depth =	3	ft
c. Single Orifice Outlet			
1) Total Area	A =	3.55	in^2
2) Diameter or W x L	D =	2 x 1.77	in
d. Multiple Orifice Outlet			
1) Area per row of perforations	A =		
2) Perforation Diameter (2-in max.)	D =		
3) No. of Perforations (columns) per Row	Perforations =		
4) No. of Rows (4-in spacing)	Rows =		
5) Total Orifice Area (Area per row) _ (Number of Rows)	Area =		

Design Procedure Form for T-3: Extended Detention Basin (Page 2 of 2)

Project:____

3. Trash Rack or Gravel Pack (check one)	Trash Rack X	Gravel Pack____		
4. Basin Length-Width Ratio (2:1 minimum)	Ratio =	3:1	L:W
5. Two-Stage Design			
a. Upper Stage			
1) Depth (2 ft min.)	Depth =	3	ft
2) Width (30 ft min.)	Width =	40	ft
3) Bottom Slope (2% to low flow channel)	Slope =	2	%
b. Bottom Stage			
1) Depth (1.5 to 3 feet deeper than Upper)	Depth =	5	ft
2) Storage Volume (5-15% of SQDV min.)	Volume =	0.08	ac-ft
6. Forebay Design			
a. Forebay Volume (5-10% of SQDV min.)	Volume =	0.03	ac-ft
b. Outlet pipe drainage time (~45 min)	Drainage Time	45	min
7. Low Flow Channel			
a. Depth (9 in min.)	Depth =	2.0	ft
b. Flow Capacity (2 _ outlet for Forebay)	Flow Capacity =	60 cfs	cfs
8. Vegetation	Native Grasses		
	Irrigated Turf	X	
	Other		
9. Embankment			
a. Interior Slope (4:1 max.)	Interior Slope =	4:1	H/V
b. Exterior Slope (3:1 max.)	Exterior Slope =	3:1	H/V
10. Access			
a. Slope (10% max.)	Slope =	9	%
b. Width (16 ft min.)	Width =	16	ft

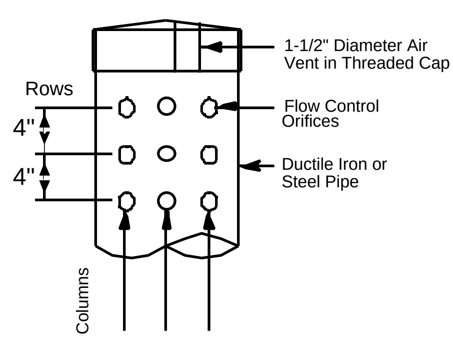
Notes: ____



Notes:
1. The outlet pipe shall be sized to control overflow into the concrete riser.
2. Alternate designs include a Hydrobrake outlet (or orifice designs) as long as the hydraulic performance matches this configuration.

OUTLET WORKS
NOT TO SCALE

Notes:
1. Minimum number of holes = 8
2. Minimum hole diameter = 1/4"
3. Maximum hole diameter = 2"



PERFORATED VERTICAL RISER PIPE
NOT TO SCALE

Maximum Number of Perforated Columns

Riser Diameter (in.)	Hole Diameter, in.			
	1/4"	1/2"	3/4"	1"
4	8	8	--	--
6	12	12	9	--
8	16	16	12	8
10	20	20	14	10
12	24	24	18	12

Hole Diameter, in.	Area of Hole (in.)^2
1/8	0.013
1/4	0.049
3/8	0.110
1/2	0.196
5/8	0.307
3/4	0.442
7/8	0.601
1	0.785

ADAPTED FROM UDFCD, 1999

Figure 5-5 . OUTLET CONFIGURATIONS USING MULTIPLE ORIFICE FLOW CONTROL

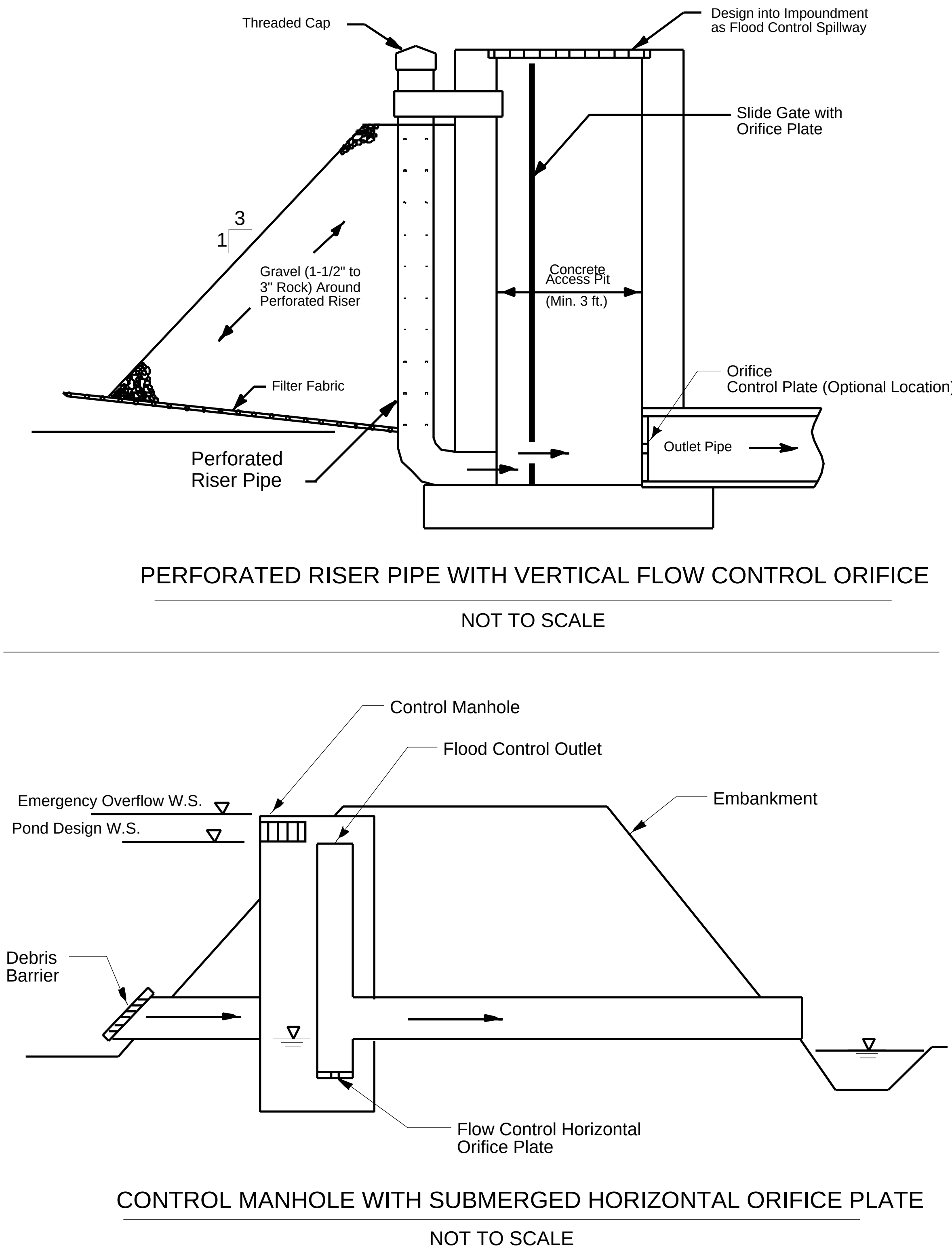


Figure 5-6. OUTLET CONFIGURATIONS USING SINGLE ORIFICE FLOW CONTROL

Maintenance Requirements

The following maintenance requirements apply to extended detention basins:

Maintenance Agreement

On-site treatment control measures are maintained by the owner/operator. Maintenance agreements between the owner/operator and the City may be required. However, if pretreatment is recommended but not included in the design, a maintenance agreement will be required. If required, a maintenance agreement must be executed by the owner/operator before the improvement plans are approved. (See Appendix C for example maintenance agreement.)

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the City's request. The Maintenance Plan should address at least the following items (see Appendix D for more detailed suggested Maintenance Plan content and format:

- Operation plan and schedule, including a site map;
- Maintenance and cleaning activities and schedule;
- Equipment and resource requirements necessary to operate and maintain facility; and
- Responsible party for operation and maintenance.

Maintenance Activities

The following activities are recommended to properly maintain Extended Detention Basins:

- Inspect basin semiannually, after each significant storm, or more frequently, if necessary. Some important items to check include: differential settlement, cracking, erosion, leakage, tree growth on the embankment, presence of burrows, the condition of riprap in the inlet, outlet, and pilot channels, sediment accumulation in the basin, and the health and density of grass turf on the basin side slopes and floor. Correct observed problems as necessary.
- Remove all litter and debris from the banks and basin bottom as required.
- Remove sediment when accumulation reaches 25 percent of the original design depth or if resuspension is observed. Clean in early spring so vegetation damaged during cleaning has time to reestablish. Clean forebay frequently to reduce frequency of main basin cleaning.
- Inspect outlet for clogging a minimum of twice per year, before and after the rainy season after large storms, or more frequently if needed.
- Trim vegetation at the beginning and end of the wet season and inspect monthly to prevent the establishment of woody vegetation and for aesthetic and vector reasons.
- Control mosquitoes, as necessary.

Description

Wet Ponds are open earthen basins that feature a permanent pool of water that is displaced by stormwater flow, in part or in total, during storm runoff events. Like Extended Detention Basins, Wet Ponds are designed to temporarily retain the SQDV of stormwater runoff and to slowly release this volume over a specified period (12 hours). Wet Ponds differ from Extended Detention Basins in that the influent runoff flow water mixes with and displaces the permanent pool as it enters the basin. The design drawdown time for Wet Ponds (12 hours) is shorter than for Extended Detention Basins (40 hours), because enhanced treatment is provided in the permanent pool. Wet Ponds differ from constructed wetlands in having a greater average depth. A dry-weather base flow is required to maintain a permanent pool. The primary removal mechanism is settling as stormwater resides in this pool, but pollutant removal, particularly nutrients, also occurs through biological activity in the pond. The basic elements of a Wet Pond are shown in Figure 5-7.

General Application

Wet ponds can improve the quality of urban runoff from roads, parking lots, residential neighborhoods, commercial areas, and industrial sites and are generally used as a regional or follow-up treatment because of its base-flow requirements. Wet pond application is appropriate in the following settings: (1) where there is a need to achieve a reasonably high level of dissolved contaminant removal and/or sediment capture; (2) in small to medium-sized regional tributary areas with available open space and drainage areas greater than about 10 acres; (3) where base flow rates or other channel flow sources are relatively consistent year-round; (4) in residential settings where aesthetic and wildlife habitat benefits can be appreciated and maintenance activities are likely to be consistently undertaken.

Wet ponds can serve essentially any size tributary area from an individual commercial development to a large residential or regional area, but are typically used for areas greater than 10 acres. Land requirements for wet ponds range from approximately two to three percent of the tributary development area. The ponds are not suitable for dense urban areas or sites with steep, unstable slopes. Additionally, ponds are not suitable for areas with long dry periods and high evaporation rates without a perennial groundwater base flow or supplemental water supply to maintain the permanent pool. This control measure is most appropriate for sites with low-permeability soils (types C or D). Discharge from Wet ponds may pose a risk to cold-water receiving waters because water retained in the permanent pool is typically heated over time.

Advantages

- Wet ponds can be designed to provide other benefits such as recreation, wildlife habitat, and open space. Safety issues must be addressed.
- Ponds are often viewed as a public amenity when integrated into a park or open-space setting.

- The permanent pool can provide significant water quality improvement across a relatively broad spectrum of constituents including dissolved nutrients.
- Widespread application with sufficient capture volume can provide significant control of channel erosion and enlargement caused by changes to stormwater flow.

Disadvantages

- There are safety concerns where there is public access.
- Mosquito and midge breeding is likely to occur in ponds.
- Ponds cannot be places on steep, unstable slopes.
- There needs to be a base flow or supplemental water if water level is to be maintained.
- Ponds require a relatively large footprint.
- Depending on volume and depth, pond designs may require approval from the State Division of Safety of Dams.

Performance

Relative pollutant removal effectiveness of a wet pond is presented in Table 5-1. Removal effectiveness of wet ponds for sediment and particulate forms of metals, nutrient, and other settleable solids is considered high to moderate. Wet ponds also remove floatables and achieve some degree of dissolved contaminant removal, but effectiveness against dissolved contaminants is low. Ponds may be used upstream of control measures that are more effective at removing soluble pollutants.

The observed pollutant removal of a wet pond is highly dependent on two factors: the volume of the permanent pool relative to the amount of runoff from the typical event in the area and the quality of the base flow that sustains the permanent pool. Studies document that if the permanent pool is much larger than the volume of runoff from an average event, then the quality of the permanent pool will determine the quality of the discharge.

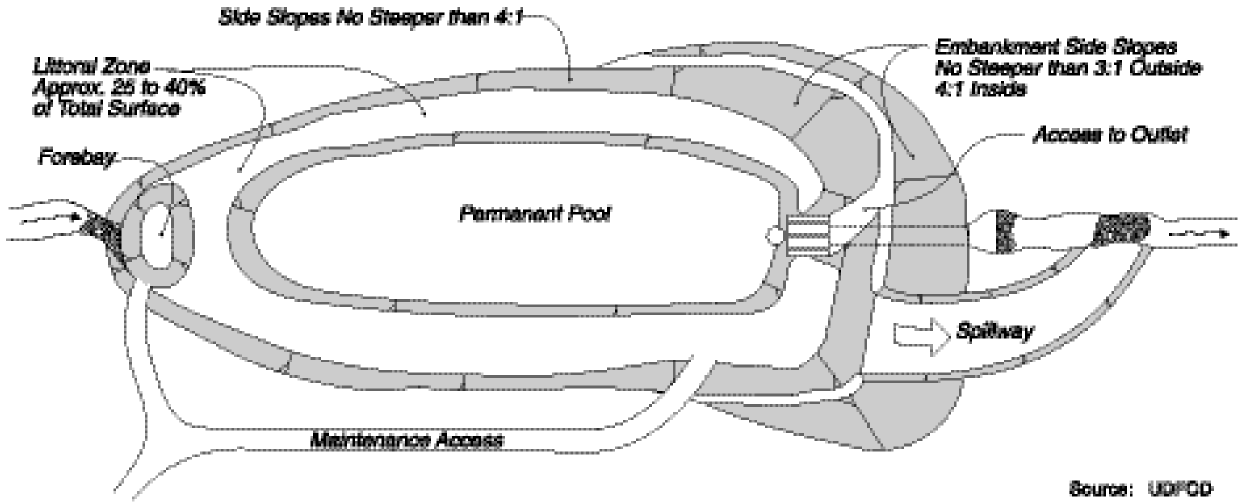
Design Criteria and Procedure

Principal design criteria for wet ponds are listed in Table 5-8.

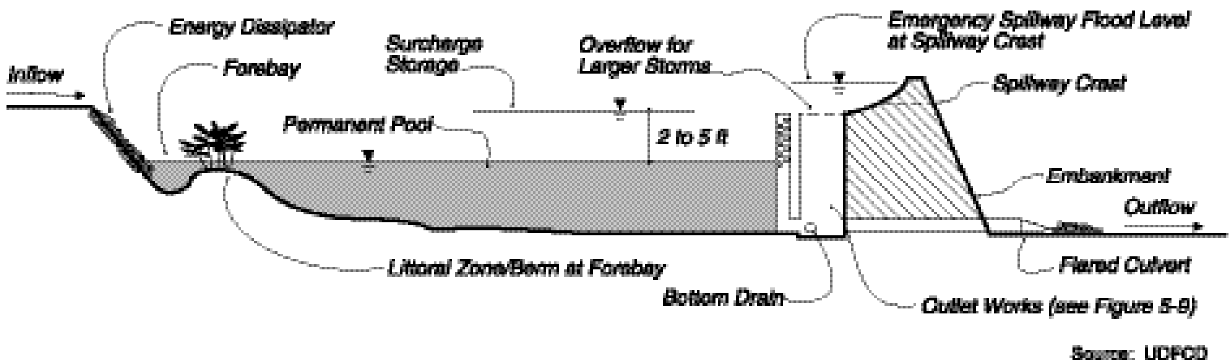
Table 5-8. Wet Pond Design Criteria

Design Parameter	Unit	Design Criteria
Drawdown time for SQDV / 50% SQDV	hrs	12
SQDV	ac-ft	80% annual capture. Use Figure 5-1 @ 12-hr drawdown
Inlet/outlet erosion control	–	Energy dissipater to reduce inlet/outlet velocity
Permanent Pool volume	–	1.0 to 1.5 × SQDV
2 Depth Zones Required	–	Littoral Zone (6-12 in deep, 25-40% of permanent pool surface area) Deeper Zone (4-8 ft average depth of remaining pond area, 12 ft max. depth)

Design Parameter	Unit	Design Criteria
Forebay volume/drain time	%/min	5-10% of SQDV. Drain time < 45 minutes
Length to width ratio (minimum)	L:W	2:1 (larger preferred)
Minimum bottom width	ft	30
Freeboard (minimum)	ft	1.0
Embankment side slope (H:V)	H:V	≥ 4:1 inside/ ≥3:1 outside (without retaining walls)
Maintenance access ramp slope (H:V)	H:V	10:1 or flatter
Maintenance access ramp width	ft	16.0 – approach paved with asphalt concrete



Plan View



Section View

Figure 5-7. Conceptual Layout of Wet Pond

Design procedure and application of design criteria for Wet Ponds are outlined in the following steps:

1. Basin Surcharge Volume — Provide a surcharge volume equal to the SQDV, based on a 12-hr drawdown time, above the lowest outlet (i.e. perforation or orifice) in the basin.

   a. Determine the percent imperviousness of the tributary area (I_a).

   b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate.

   c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 12-hr drawdown and I_{wq} value from step 1.b.

   d. Calculate the SQDV in acre-ft as follows:

   $$SQDV = (V_u/2) \times Area$$

   where

   Area = Watershed area tributary to Wet Pond (acres)

2. Permanent Pool — The permanent pool provides stormwater quality enhancement between storm runoff events through biochemical processes and continuing sedimentation.

   a. Determine the volume of the permanent pool (V_p), which is 1.0 to 1.5 times the SQDV.

   b. Depth Zones (see Figure 5-8)

   Littoral Zone should be between 6 to 12 inches deep that is between 25 to 40 percent of the permanent pool surface for aquatic plant growth along the perimeter of the pool.

   Deeper Zone should be 4 to 8 feet average depth with a maximum depth of 12 feet. This zone should cover the remaining pond area and promote sedimentation and nutrient uptake by phytoplankton.

3. Base Flow — A net influx of water must be available through a perennial base flow and must exceed the losses. The following equation and parameters can be used to estimate the net quantity of base flow available at the time.

   $$Q_{net} = Q_{inflow} - Q_{E\text{-}P} - Q_{seepage} - Q_{ET}$$

   where

   Q_{net} = Net quantity of base flow (ac-ft/yr)

   Q_{inflow} = Estimated base flow (ac-ft/yr). (Estimate by seasonal measurements and/or comparison to similar watersheds.)

$Q_{E\text{-}P}$	=	Loss due to evaporation minus the precipitation (ac-ft/yr)
$Q_{seepage}$	=	Loss or gain due to seepage to groundwater (ac-ft/yr)
Q_{ET}	=	Loss due to evapotranspiration (additional loss through plant area above water surface not including the water surface)

4. Outlet Works

The Outlet Works are to be designed to release the SQDV (i.e. not Design Volume) over a 12-hour period. Refer to Figure 5-9 for schematics pertaining to structure geometry; grates, trash racks, and outlet.

a. For perforated pipe outlets or vertical plates with multiple orifices, use the following equation to determine required area per row of perforations, based on the SQDV(acre-ft) and depth of water above the centerline of the bottom perforation D (ft).

$$\text{Area/row (in}^2) = \text{SQDV}/K_{12}$$

where

$$K_{12} = 0.008D^2 + 0.056D - 0.012$$

Select appropriate perforation diameter and number of perforations per row (columns) with the objective of minimizing the number of columns and using a maximum perforation diameter of 2 inches. Rows are spaced at 4 inches on center from the bottom perforation. Thus, there will be 3 rows for each foot of depth plus the top row. The number of rows (nr) may be determined as follows:

$$nr = 1 + (D \times 3)$$

Calculate total outlet area by multiplying the area per row by number of rows.

$$\text{Total Orifice Area} = \text{area/row} \times nr$$

b. For single orifice outlet control or single row of orifices at the basin bottom surface elevation use the following equation based on the SQDV (acre-ft) and depth of water above orifice centerline D (ft) to determine orifice area (in^2):

$$\text{Total orifice area} = (\text{SQDV}) \div [(60.19)(D^{0.5})(T)]$$

where

T = drawdown period (hrs) = 12 hrs

5. Basin Side Slopes

Side slopes should be stable and sufficiently gentle to limit rill erosion and to facilitate maintenance. Side slopes above the permanent pool should be no steeper than 4:1, preferable 5:1 or flatter. The littoral zone should be very flat (40:1 or flatter) with the depth ranging from 6 inches near the shore and extending to no more than 12 inches at the furthest point from the shore. The side slope below the littoral zone shall be 3:1 or flatter.

6. Forebay Design	The forebay provides a location for sedimentation of larger particles and has a solid bottom surface to facilitate mechanical removal of accumulated sediment. The forebay volume should be 5 to 10 percent of the SQDV. A berm consisting of rock and topsoil mixture should be part of the littoral bench to create the forebay and have a minimum top width of 8 feet and side slopes no steeper than 4:1.
7. Inlet/Outlet Design	Basin inlet and outlet points should provided with an energy dissipation structure and/or erosion protection.
8. Vegetation	Bottom vegetation provides erosion protection and sediment entrapment. Berms, and side slopes may be planted with native grasses or with irrigated turf. The shallow littoral bench should have a 4 to 6 inch thick organic topsoil layer and be vegetated with aquatic species.
9. Embankment	Design embankments to conform to State of California Division of Safety of Dams requirements, if the basin dimensions cause it to fall under that agency's jurisdiction. Interior slopes should be no steeper than 4:1 and exterior slopes no steeper than 3:1. Flatter slopes are preferable.
10. Access	All-weather access to the bottom, forebay, and outlet works shall be provided for maintenance vehicles. Maximum grades of access ramps should be 10 percent and minimum width should be 16 feet. Ramps should be paved with concrete.
11. Bypass	Provide for bypass or overflow of runoff volumes in excess of the SQDV. Spillway and overflow structures should be designed in accordance with applicable standards of the City.
12. Underdrains	Provide underdrain trenches near the edge of the pond. The trenches should be no less than 12 inches wide filled with ASTM C-33 sand to within 2 feet of the pond's permanent pool water surface, and with an underdrain pipe connected through a valve to the outlet. These underdrains will permit the drying out of the pond when it has to be "mucked out" to restore volume lost due to sediment deposition.

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

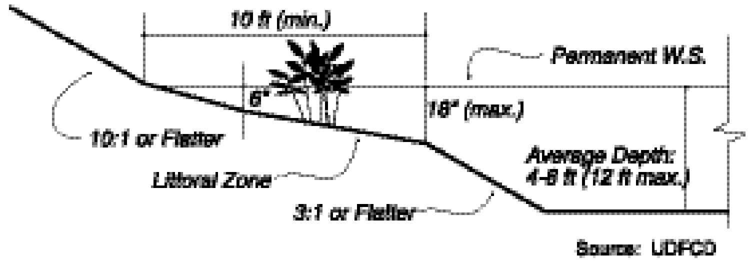


Figure 5-8. Depth Zones for Wet Pond

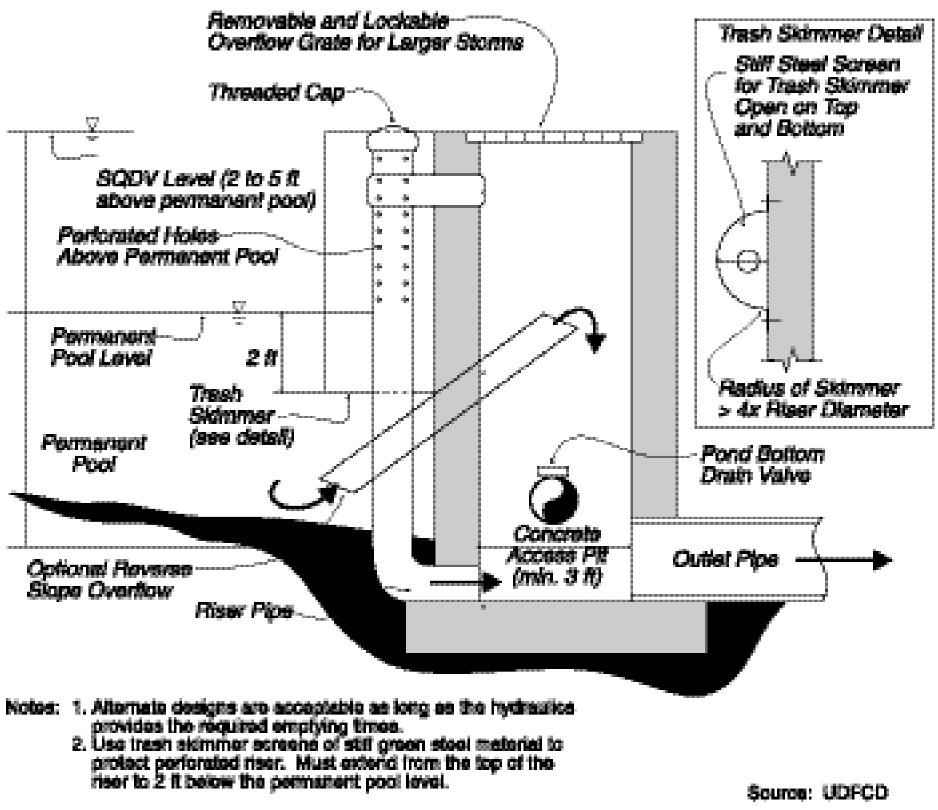


Figure 5-9. Outlet Works for Wet Pond

Design Procedure Form for T-4: Wet Pond (Page 1 of 3)

Designer:____________________

Company:____________________

Date:____________________

Project:____________________

Location:____________________

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	64	%
b. Effective Imperviousness (Determine using Figure 3-4)	I_{wq} =	60	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 12-hr drawdown and I_{wq}	V_u=	0.23	in
d. Watershed Area Tributary to Wet Pond	Area =	100.0	ac
Calculate SQDV = (V_u/12) × Area	SQDV =	1.91	ac-ft
2. Permanent Pool			
a. Volume of Permanent Pool (1.0 to 1.5 times SQDV min.)	V_p =	1.91	ac-ft
b. Depth			
1) Littoral Zone Depth (6 to 12 in)	Depth =	1.0	ft
2) Deeper Zone Depth (4 to 8 ft average, 10 ft max.)	Average Depth =	6.0	ft
	Max Depth =	9.0	ft
c, Permanent Pool Surface Area			
1) Littoral Zone Area (25-40% Permanent Pool Surface)	Area =	0.175	ac
	% of total	30.0	%
2) Deeper Zone Area (60-40% Permanent Pool Surface)	Area =	0.408	ac
	% of total	70.0	%
3) Total Area	Total area =	0.583	ac
3. Estimated Net Base Flow (must be > 0)			
$Q_{net} = Q_{inflow} - Q_{evap} - Q_{seepage} - Q_{evapotranspiration}$	Q_{inflow} =	1.91	ac-ft
	Q_{evap} =	0.3	ac-ft
	$Q_{seepage}$ =	0.8	ac-ft
	$Q_{evapotranspiration}$	0.8	ac-ft
	Q_{net} =	0.41	ac-ft

Design Procedure Form for T-4: Wet Pond (Page 2 of 3)

Project:______________________________

4. Outlet Works			
a. Outlet Type (check one)	Single Orifice	X (1 row)	
	Multi-orifice Plate		
	Perforated Pipe		
	Other		
b. Depth of water above bottom orifice	Depth =	3.0	ft
c. Single Orifice Outlet			
1) Total Area	A =	66.5	in^2
2) Diameter or L x W	D =	4 @ 4.6	in
d. Multiple Orifice Outlet			
1) Area per row of perforations	A =		
2) Perforation Diameter (2-in max.)	D =		
3) No. of Perforations (columns) per Row	Perforations =		
4) No. of Rows (4-in spacing)	Rows =		
5) Total Orifice Area (Area per row) × (Number of Rows)	Area =		
5. Trash Rack or Gravel Pack Present?	Yes/No	Yes	
6. Basin Shape			
a. Length-Width Ratio	Ratio =	3:1	L/W
7. Forebay Design			
a. Forebay Volume (5-10% of SQDV min.)	Volume =	0.12	ac-ft
b. Outlet pipe drainage time (< 45 minutes)	Drainage Time	45	min
8. Embankment Slope			
a. Interior Slope (4:1 max.)	Interior Slope =	4:1	L/W
b, Exterior Slope (3:1 max.)	Exterior Slope =	3:1	L/W

Design Procedure Form for T-4: Wet Pond (Page 3 of 3)

Project:______________________________

9. Vegetation (Check type used or describe "Other")	__X__ Native Grasses _____ Irrigated Turf Grass _____ Emergent Aquatic Plants (specify type / density) _____ Other ____________________
10. Underdrains Provided?	Yes /No ____No____

Notes:

Maintenance Requirements

The following maintenance requirements apply to wet ponds:

Maintenance Agreement

On-site treatment control measures are maintained by the owner/operator. Maintenance agreements between the owner/operator and the City may be required. However, if pretreatment is recommended but not included in the design, a maintenance agreement will be required. If required, a maintenance agreement must be executed by the owner/operator before the improvement plans are approved (See Appendix C for example maintenance agreement.).

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the City's request. The Maintenance Plan should address at least the following items (see Appendix D for more detailed suggested Maintenance Plan content and format:

- Operation plan and schedule, including a site map;
- Maintenance and cleaning activities and schedule;
- Equipment and resource requirements necessary to operate and maintain facility; and
- Responsible party for operation and maintenance.

Maintenance Activities

The following activities are recommended to properly maintain Wet Ponds:

- Considerable resources must be committed to maintain aquatic vegetation in Wet Ponds to control mosquito propagation and to maintain effective permanent pool volume.
- Inspect ponds semiannually, after each significant storm, or more frequently, if necessary. Some important items to check include: differential settlement, cracking, erosion, leakage, tree growth on the embankment, the condition of riprap in the inlet, outlet, and pilot channels, sediment accumulation in the basin, and the health and density of grass turf on the basin side slopes and floor. Correct observed problems as necessary.
- Remove all litter and debris from the banks and basin bottom as required.
- Remove sediment when accumulation reaches 25 percent of original design depth, or if resuspension is observed. Clean in early spring so vegetation damaged during cleaning has time to reestablish. Clean forebay frequently to reduce frequency of main basin cleaning.
- Inspect outlet for clogging a minimum of twice per year, before and after the rainy season after large storms, and more frequently if needed.

Description

A Constructed Wetland is a single-stage treatment system consisting of a forebay and a permanent pool with aquatic plants. Constructed wetlands function similarly to Wet Ponds in that influent runoff flow water mixes with and displaces a permanent pool as it enters the basin. The surcharge volume above the permanent pool is slowly released over a specified period (24 hours for SQDV). Constructed Wetlands require a longer release period for the surcharge volume than Wet Ponds, because the depth and volume of the permanent pool for Constructed Wetlands are less than for Wet Ponds. A base flow is required to maintain the permanent water pool. Constructed Wetlands also differ from Wet Ponds in terms of the extensive presence of aquatic plants. Plants provide energy dissipation and enhance pollutant removal by sedimentation and biological uptake. A conceptual layout of a Constructed Wetland is shown in Figure 5-10.

Constructed Wetlands differ from natural wetlands in that they are man-made and are designed to enhance stormwater quality. Diversion of stormwater to natural wetlands is not recommended because natural wetlands need to be protected from adverse effects of development. This is especially important because natural wetlands provide stormwater and flood control on a regional scale. Natural wetlands can be incorporated into the constructed wetlands system, but such action requires the approval of federal and state regulators. Constructed wetlands are generally not allowed to be used to mitigate the loss of natural wetlands.

General Application

Constructed wetlands are widely applicable stormwater management practice and can be used over a broad range of storm frequencies and sizes, drainage areas, and land use types. Land uses for which this BMP is appropriate include large residential developments and commercial, institutional, and industrial areas where incorporation of a green space and a wetland into the landscape is desirable and feasible. Constructed wetlands can be used effectively in combination with upstream treatment controls such as vegetated buffer strips and vegetated swales.

Wetlands generally consume relatively large areas (typically four to six percent of the tributary area) and are usually larger than Wet Ponds because the average depth is less. This control measure is most appropriate for sites with low-permeability soils (type C and D) that will support aquatic plant growth. Infiltration through a wetland bottom cannot be relied upon because the bottom is either covered by soils of low permeability or because the groundwater is higher than the wetland bottom. Wetland bottom channels require a near-zero slope. A base flow of water is required to maintain aquatic conditions.

Advantages

- Constructed wetlands can provide substantial wildlife habitat and passive recreation.
- Due to the presence of the permanent wet pool, constructed wetlands can provide significant water quality improvement for many constituents including dissolved nutrients.
- Widespread application with sufficient capture volume can provide significant control of channel erosion and enlargement caused by changes to stormwater flow.

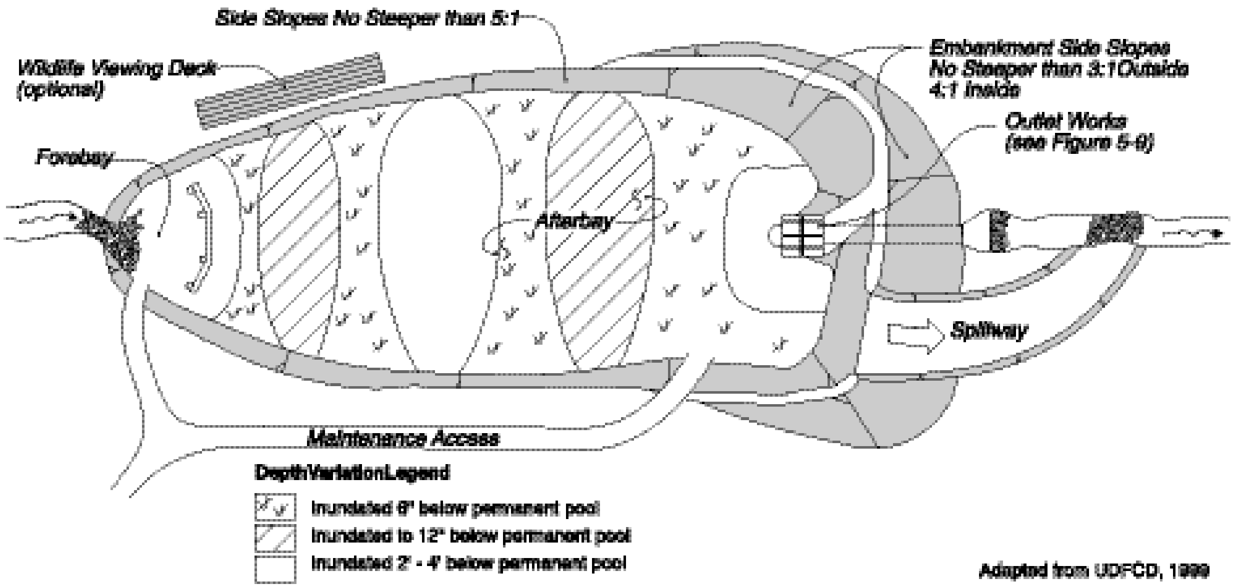
Disadvantages

- Wetlands must have a continuous base flow to maintain aquatic plants.
- There may be some aesthetic concerns about a facility that looks swampy.
- There are concerns about safety when wetlands are constructed where there is public access.
- Mosquito and midge breeding is likely to occur in wetlands.
- Wetlands cannot be placed on steep, unstable slopes and require a relatively large footprint.
- Depending on size, wetland design may require approval by the Division of Safety of Dams.

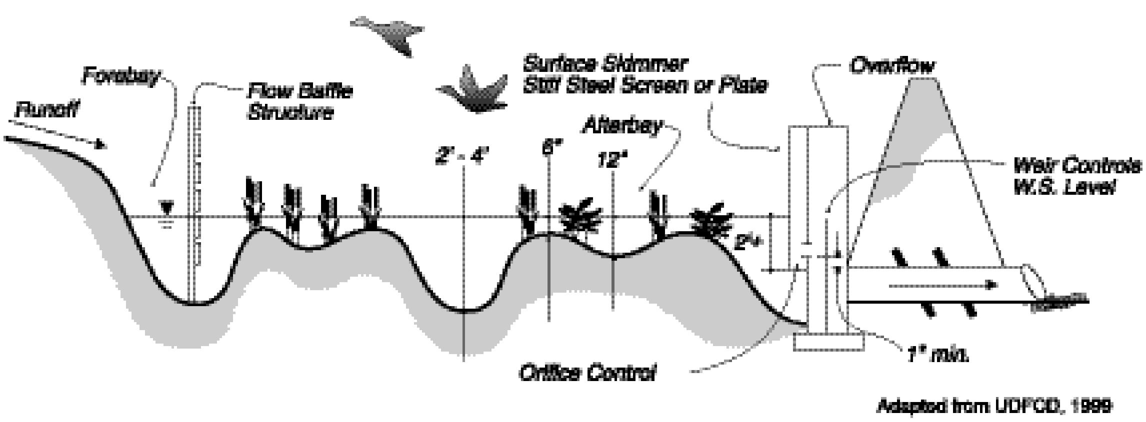
Performance

Relative pollutant removal effectiveness of a constructed wetland is presented in Table 5-1. Wetlands remove a variety of constituents, but their effectiveness varies significantly. With periodic sediment removal and plant harvesting, expected removal efficiencies for sediments, organic matter, and metals can be moderate to high; for phosphorus and nitrogen, low to moderate. Pollutants are removed primarily through sedimentation and entrapment, with some removal through biological uptake by vegetation and microorganisms. Without a continuous base flow, salts and algae can concentrate in the water column and can be released into the receiving water in higher levels at the beginning of storm events. Harvesting aquatic plants and periodic removal of sediment also removes nutrients and pollutants associated with the sediment.

One concern about the long-term performance of wetlands is associated with the vegetation density. If vegetation covers the majority of the facility, open water is confined to few well defined channels, which can limit mixing of stormwater runoff with the permanent pool and reduce pollutant removal.



Plan View



Section View

Figure 5-10. Conceptual Layout of Constructed Wetland

Design Criteria and Procedure

Principal design criteria for constructed wetlands are listed in Table 5-9.

Table 5-9. Constructed Wetland Design Criteria

Design Parameter	Unit	Design Criteria
Drawdown time for SQDV/50% SQDV	hrs	24
SQDV	ac-ft	80% annual capture. Use Figure 5-1 @ 24-hr drawdown
Permanent pool volume (minimum)	%	75% of SQDV
Inlet/outlet erosion control	–	Energy dissipater to reduce inlet/outlet velocity
Permanent Pool Area/Depth		
Forebay, free water surface, and outlet areas	%/ft	30-50% of the permanent pool surface area/2 to 4ft
Wetland zones with emergent vegetation	%/ft	50-70% of the permanent pool surface area/ 0.5 to 1.0 ft (30-50% should be 0.5 ft deep)
Forebay volume	%	5-10 % of SQDV
Surcharge depth above permanent pool	ft	2.0 ft maximum
Length to width ratio (minimum)	–	2:1 (larger preferred)
Freeboard (minimum)	ft	1.0
Wetland (Littoral) zone bottom slope	%	10.0 maximum
Embankment side slope	H:V	≥ 4:1 inside/ ≥3:1 outside (without retaining walls)
Maintenance access ramp slope (H:V)	H:V	10:1 or flatter
Maintenance access ramp width	ft	16.0 – approach paved with asphalt concrete

Design procedure and application of design criteria are outlined in the following steps:

1. Basin Storage Volume — Provide a storage volume equal to 100 percent of the SQDV, based on a 24-hr drawdown time, above the lowest outlet (i.e. perforation or orifice) in the basin.

    a. Determine the percent imperviousness of the tributary area (I_a).

    b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate.

    c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 24-hr drawdown and I_{wq} value from step 1.b.

    d. Calculate the SQDV in acre-ft as follows:

$$SQDV = (V_u/12) \times Area$$

where

Area = Watershed area tributary to Constructed Wetland (acres)

2. Basin Depth/Volume

The volume of the permanent wetland pool shall be not less than 75% of the SQDV. Distribution of wetland area is needed for a diverse ecology. Distribute component areas as follows:

Components	Percent of Permanent Pool Surface Area	Design Water Depth
Forebay, outlet and free water surface areas	30-50%	2 to 4 feet
Wetland zones with emergent vegetation	50-70%	6 to 12 inches (1/3 to 1/2 of this area should be 6 inches deep with bottom slope ≤ 10%)

3. Depth of Surcharge

The surcharge depth of the SQDV above the permanent pool's water surface should not exceed 2.0 feet.

4. Outlet Works

Provide outlet works that limit the SQDV depth to 2 feet or less. The Outlet Works are to be designed to release the SQDV over at least a 40 hour period. A single orifice outlet control is depicted in Figure 5-10.

For single orifice outlet control or single row of orifices at the basin bottom surface elevation (see Figures 5-6), use the following equation based on the SQDV (ft^3) and depth of water above orifice centerline D (ft) to determine orifice area (in^2):

$$\text{Total Orifice Area} = (SQDV) \div [(60.19)(D^{0.5})(T)]$$

where

T = drawdown period (hrs) = 24 hrs

For perforated pipe outlets or vertical plates with multiple orifices (see Figure 5-5), use the following equation to determine required area per row of perforations, based on the SQDV (ac-ft) and depth of water above centerline of the bottom perforation D (ft).

$$\text{Area/row } (in^2) = SQDV/K_{40}$$

where

$$K_{40} = 0.012D^2 + 0.14D - 0.06$$

Select appropriate perforation diameter and number of perforations per row (columns) with the objective of minimizing the number of columns and using a maximum perforation diameter of 2 inches. Rows are spaced at 4 inches on center from the bottom perforation. Thus, there will be 3 rows for each foot of depth plus the top row. The number of rows (nr) may be determined as follows:

$$nr = 1 + (D_{BS} \times 3)$$

Calculate total outlet area by multiplying the area per row by number of rows.

$$\text{Total Orifice Area} = \text{area/row} \times nr$$

5. Basin Use — Determine if flood storage or other uses will be provided for above the wetland surcharge storage or in an upstream facility. Design for combined uses when they are provided for.

6. Basin Shape — Whenever possible, shape the basin with a gradual expansion from the inlet and a gradual contraction toward the outlet. The length to width ratio should be between 2:1 to 4:1 with a 3:1 recommended. Internal baffling with berms or modification of inlet and outlet points may be necessary to achieve this ratio.

7. Basin Side Slopes — Side slopes should be stable and sufficiently gentle to limit rill erosion and to facilitate maintenance. Internal side slopes should be no steeper than 4:1, external side slopes should be less than 3:1.

8. Base Flow — A net influx of water must be available through a perennial base flow and must exceed the losses. The following equation and parameters can be used to estimate the net quantity of base flow available at the time.

$$Q_{net} = Q_{inflow} - Q_{E\text{-}P} - Q_{seepage} - Q_{ET}$$

where

Q_{net}	=	Net quantity of base flow (ac-ft/yr)
Q_{inflow}	=	Estimated base flow (ac-ft/yr). (Estimate by seasonal measurements and/or comparison to similar watersheds.)
$Q_{E\text{-}P}$	=	Loss due to evaporation minus the precipitation (ac-ft/yr)
$Q_{seepage}$	=	Loss or gain due to seepage to groundwater (ac-ft/yr)
Q_{ET}	=	Loss due to evapotranspiration (additional loss through plant area above water surface not including the water surface)

9. Inlet/Outlet Design — Basin inlet and outlet points should provided with an energy dissipation structure and/or erosion protection. Outlets should be

	placed in an offbay that is at least 3 feet deep. The outlet should be protected from clogging by a skimmer shield that starts at the bottom of the permanent pool and extends above the maximum SQDV depth. Also, provide for a trash rack.
10. Forebay/Afterbay	The forebay provides a location for sedimentation of larger particles and has a solid bottom surface to facilitate mechanical removal of accumulated sediment. The after bay is optional. The forebay volume should be 5 to 10 % of the SQDV. Depth should be 2.0 to 4.0 ft.
11. Vegetation	Selected wetland plants and grasses should be planted in the wetland bottom. The shallow littoral bench should have a 4 to 6 inch layer of organic topsoil. Berms and side-sloping areas should be planted with native or irrigated turf grasses. The selection of plant species for a constructed wetland shall take into consideration the water fluctuation likely to occur in the wetland. Permanent pool water level should controlled as necessary to establish wetland plants and raised to final operating level after plants are established.
12. Access	All-weather access to the forebay, and outlet works shall be provided for maintenance vehicles. Maximum grades of access ramps should be 10 percent and minimum width should be 16 feet. Ramps should be paved with concrete.
13. Bypass	Provide for bypass or overflow of runoff volumes in excess of the SQDV. Spillway and overflow structures should be designed in accordance with applicable standards of the City.

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-5: Constructed Wetland (Page 1 of 3)

Designer:________________________________

Company:________________________________

Date:________________________________

Project:________________________________

Location:________________________________

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	50	%
b. Effective Imperviousness (Determine using Figure 3-4)	I_{wq} =	50	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40-hr drawdown and I_{wq}	V_u=	0.28	in
d. Watershed Area Tributary to Wetland	Area =	100	ac
e. Calculate SQDV SQDV = (V_u/12) × Area	SQDV =	2.33	ac-ft
2. Wetland Pond Volume, Depth, and Water Surface Area		**Minimums**	
a. Calculated Requirements, Minimum Permanent Pool: $Vol_{pool} \geq 0.75 \times$ SQDV	Vol_{pool} >	1.75	ac-ft
	Water Area>	0.70	ac, estimated
		Actual Design	
	Vol_{pool} =	1.80	ac-ft, actual
	Water Area =	1.20	ac, actual
b. Forebay Depth Range = 2.0 – 4.0 ft	Depth =	3.0	ft
Volume Range = 5-10 % of SQDV	Volume =	0.09	ac-ft,% = 5.0
c. Outlet Pool Depth Range = 2.0 – 4.0 ft	Depth =	3.0	ft
Volume Range = 6-10% of SQDV	Volume =	0.18	ac-ft,% = 10.0

Continued on next page

Design Procedure Form for T-5: Constructed Wetland(Page 2 of 3)

Project:____

3. Wetland Pond Volume, Depth, and Water Surface Area (Continued)			
d. Free Water Surface Areas (Area = 30-50% combined) (Depth Range = 2.0-4.0 ft)	Depth =	2.0	ft
	Area =	0.60	ac, % = 50
	Volume =	1.20	ac-ft
e. Wetland Zones with Emergent Vegetation (Depth Range = 6-12 in) (Area = 50-70%)	Depth =	1.0	ft
	Area =	0.60	ac, % = 50
	Volume =	0.60	ac-ft
4. Estimated Net Base Flow (must be > 0)			
$Q_{net} = Q_{inflow} - Q_{evap} - Q_{seepage} - Q_{evapotranspiration}$	Q_{inflow} =	362.0	ac-ft
	Q_{evap} =	1.40	ac-ft
	$Q_{seepage}$ =	2.80	ac-ft
	$Q_{evapotranspiration}$	1.50	ac-ft
	Q_{net} =	356.30	ac-ft
5. Outlet Works			
a. Outlet Type (check one)	Single Orifice	X	
	Multi-orifice Plate		
	Perforated Pipe		
	Other		
b. Depth of water above bottom orifice	Depth =	3.0	ft
c. Single Orifice Outlet			
1) Total Area	A =	40.56	in^2
2) Diameter (or L x W)	D =	5 x 8.11	in^2
d. Multiple Orifice Outlet			
1) Area per row of perforations	A =		
2) Perforation Diameter (2-in max.)	D =		
3) No. of Perforations (columns) per Row	Perforations =		
4) No. of Rows (4-in spacing)	Rows =		
5) Total Orifice Area (Area per row) _ (Number of Rows)	Area =		

Design Procedure Form for T-5: Constructed Wetland(Page 3 of 3)

Project:____

6. Trash Rack or Gravel Pack Present?	Yes/No ___Yes__
7. Basin Shape a. Length-Width Ratio	Ratio = ___3:1___ L:W
8. Embankment Side Slope a. Interior Side Slope (4:1 max.) b, Exterior Side Slope (3:1 max.)	Int. Side Slope = ___4:1___ L:W Ext. Side Slope = ___3:1___ L:W
9. Vegetation (Check type used or describe "Other")	__X__ Native Grasses _____ Irrigated Turf Grass __X__ Emergent Aquatic Plants (specify type / density)* _____ Other ________________ *Describe Species Density and Mix: ____See attached specification________

Notes:

Maintenance Requirements

The following maintenance requirements apply to Constructed Wetlands:

Maintenance Agreement

On-site treatment control measures are maintained by the owner/operator. Maintenance agreements between the owner/operator and the City may be required. However, if pretreatment is recommended but not included in the design, a maintenance agreement will be required. If required, a maintenance agreement must be executed by the owner/operator before the improvement plans are approved.

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the City's request. The Maintenance Plan should address items such as:

- Operation plan and schedule, including a site map
- Maintenance and cleaning activities and schedule
- Equipment and resource requirements necessary to operate and maintain facility
- Responsible party for operation and maintenance

See Appendix D for additional Maintenance Plan requirements and suggested template.

Maintenance Activities

The following activities are recommended to properly maintain constructed wetlands:

- Considerable resources must be committed to maintain aquatic vegetation in Wet Ponds to control mosquito propagation and to maintain effective permanent pool volume.
- Inspect ponds semiannually, after each significant storm, or more frequently, if necessary. Some important items to check include: differential settlement, cracking, erosion, leakage, tree growth on the embankment, the condition of riprap in the inlet, outlet, and pilot channels, sediment accumulation in the basin, and the health and density of grass turf on the basin side slopes and floor. Correct observed problems as necessary.
- Remove all litter and debris from the banks and basin bottom as required.
- Remove sediment when accumulation reaches 10 percent of original design depth, or if resuspension is observed. Clean in early spring so vegetation damaged during cleaning has time to reestablish. Clean forebay frequently to reduce frequency of main basin cleaning. Sediment removal may not be required in the main pool area for as long as 20 years.
- Inspect outlet for clogging a minimum of twice per year, before and after the rainy season after large storms, and more frequently if needed.
- If permitted by the Department of Fish and Game or other agency regulations, stock Wet Ponds regularly with mosquito fish to enhance natural mosquito and midge control.
- Harvest vegetation annually, or more frequently, for vector control.

Detention Basin/Sand Filter

Description

A Detention Basin/Sand Filter consists of a runoff storage zone underlain by a sand bed filter with an underdrain system constructed in an earthen basin. The basin is divided into a forebay settling basin to remove large sediment followed by sand filter basin. During storm events, runoff accumulates in the surcharge zone and gradually infiltrates into the underlying sand bed, filling the void spaces of the sand. The underdrain gradually dewaters the sand bed and discharges the runoff to a downstream conveyance. Schematic plan and section views of a typical detention basin/sand filter are shown in Figure 5-11.

General Application

Detention Basin/Sand Filters are typically applied to areas with no base flow and where sediment loads are relatively low. Higher sediment loads will cause clogging of the sand filter bed. This control measure can be placed downstream of other control measures that are more effective in removing sediments.

Detention Basin/Sand Filters can be used for tributary areas of up to 100 acres. Since an underdrain system is incorporated into its system, detention basin/sand filters are suited to most soil types and the presence of sandy soils is not a requirement. Detention Basin/Sand Filters are best suited to flat or gently sloping terrain because of the need to construct zero-slope filter beds.

Advantages

- Detention Basin/Sand Filters are effective in enhancing water quality through sedimentation and filtration.

Disadvantages

- The primary disadvantage of the Detention Basin/Sand Filters is the potential for clogging of the filter media. As a result, these systems should not be put into operation while construction activities are taking place in the tributary area.
- Maintenance requirements to maintain permeability of the filter media can be high if sediment loads are excessive.

Performance

Relative pollutant removal effectiveness of a detention basin/sand filter is presented in Table 5-1. Removal effectiveness of detention basin/sand filters for sediment and particulate forms of metals, nutrients, and other pollutants is considered high to moderate. The removal efficiency of dissolved pollutants is considered low.

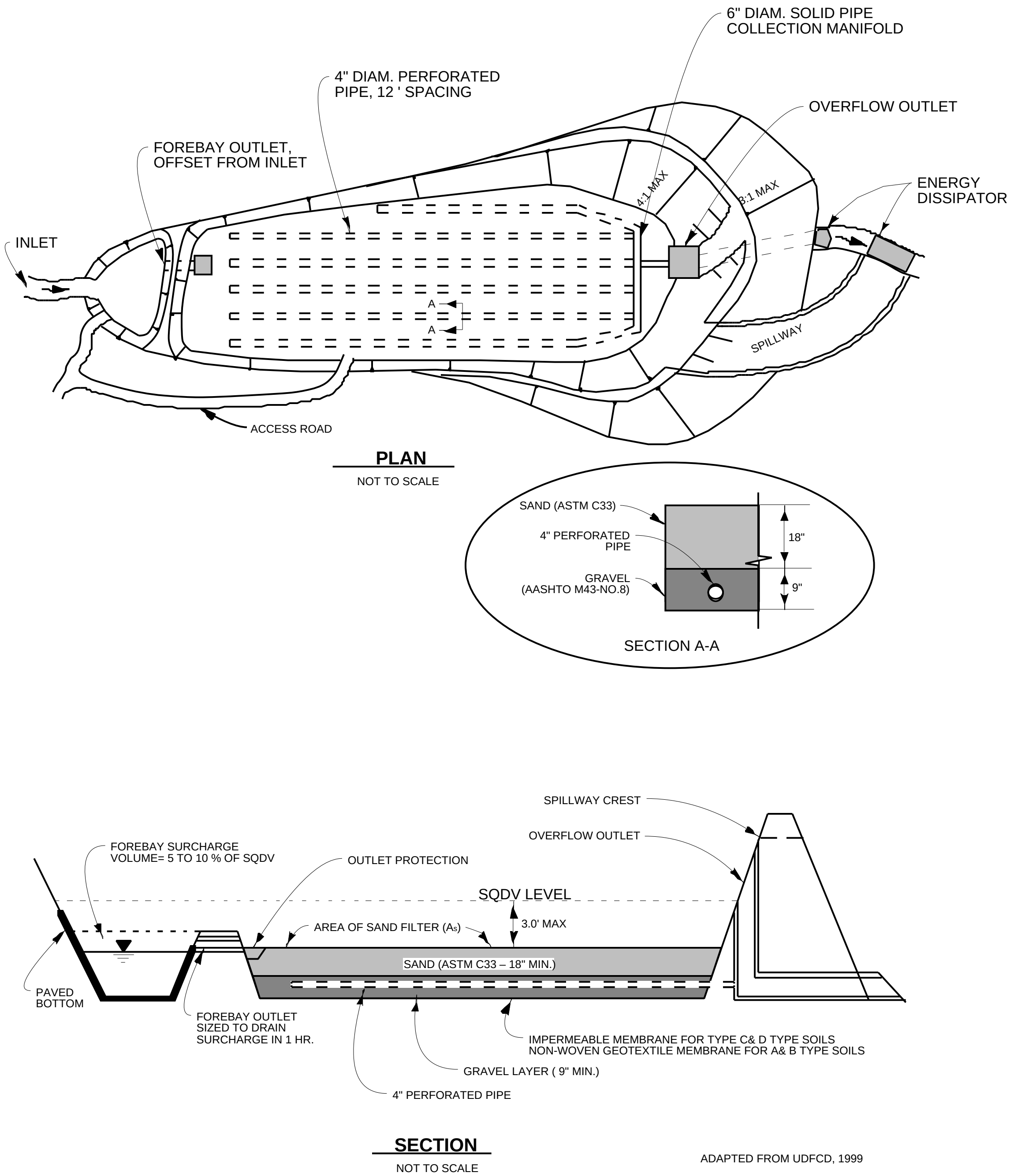


Figure 5-11. Detention Basin/Sand Filter

Design Criteria and Procedure

Principal design criteria for Detention Basin/Sand Filters are listed in Table 5-10.

Table 5-10. Detention Basin/Sand Filter Design Criteria

Design Parameter	Unit	Design Criteria
Drawdown time for SQDV/50% SQDV	hrs	40/12 (minimum)
SQDV	ac-ft	80% annual capture. Use Figure 5-1 @ 40-hr drawdown
Forebay surcharge volume	%	5-10% of SQDV
Max depth at SQDV	ft	3 ft
Inlet/outlet erosion control	–	Energy dissipater to reduce inlet/outlet velocity
Length to width ratio (minimum)	–	2:1 (larger preferred)
Freeboard (minimum)	ft	1.0
Filter bed media	--	Sand: 18-in, Gravel: 9-in
Embankment side slope (H:V)	H:V	≥ 4:1 inside/ ≥3:1 outside (without retaining walls)
Maintenance access ramp slope (H:V)	H:V	10:1 or flatter
Maintenance access ramp width	ft	16.0 – approach paved with asphalt concrete

Design procedure and application of design criteria are outlined in the following steps:

1. Basin Storage Volume — Provide a storage volume equal to 100 percent of the SQDV, based on a 40-hr drawdown time, above the sand bed of the basin.

   a. Determine the percent imperviousness of the tributary area (I_a).

   b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate.

   c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 40-hr drawdown and I_{wq} value from step 1.b.

   d. Calculate the SQDV in acre-ft as follows:

   $$SQDV = (V_u/12) \times Area$$

   where

   Area = Watershed area tributary to Detention Basin/Sand Filter (acres)

2. Basin Depth — Maximum design volume depth should be 3 feet.

3. Filter Surface Area — Calculate the minimum sand filter area (A_s at the basin's bottom with the following equation:

$$A_s = (SQDV/3) \times 43{,}560 \text{ ft}^2$$

4. Filter Bed	An 18-inch layer of sand (ASTM C 33) over a 9-inch gravel layer (ASSHTO M43-No. 8) shall line the entire Detention Basin/Sand Filter for purposes of filtering and draining the SQDV. If expansive soils are a concern or if the tributary catchment has chemical or petroleum products handled or stored, install an impermeable membrane below the gravel layer.
5. Outlet Works	A grated outlet structure with overflow should be provided to convey flows in excess of the SQDV out of the basin.

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-6: Detention Basin/Sand Filter

Designer:___________________________________

Company:___________________________________

Date:___________________________________

Project:___________________________________

Location:___________________________________

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	64	%
b. Effective Imperviousness (Determine using Figure 3-4)	I_{wq} =	60	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40-hr drawdown and I_{wq}	V_u=	0.41	in
d. Watershed Area Tributary to detention basin/sand filter	Area =	10.0	ac
e. Calculate SQDV SQDV = (V_u/12) × Area	SQDV =	0.34	ac-ft
2. Filter Surface Area (A_s)			
a. A_s (min.) = (SQDV/3) × 43,560 ft^2	A_s (min) =	4,961	ft^3
b. Design A_s	A_s =	5,000	ft^2
3. Design basin depth, based on design filter area			
D = Design Volume/Design A_s	D =	3.0	ft
4. Filter Bed			
a) ASTM C33 Sand Layer (18-in min.)		18	in
b) ASSHTO M43-No.8 Gravel Layer (9-in min.)		9	in

Notes:

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Maintenance Requirements

The following maintenance requirements apply to Detention Basin/Sand Filters:

Maintenance Agreement

On-site treatment control measures are maintained by the owner/operator. Maintenance agreements between the owner/operator and the City may be required. However, if pretreatment is recommended but not included in the design, a maintenance agreement will be required. If required, a maintenance agreement must be executed by the owner/operator before the improvement plans are approved. See Appendix C for example maintenance and access agreement.

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the City's request. The Maintenance Plan should address items such as:

- Operation plan and schedule, including a site map;
- Maintenance and cleaning activities and schedule;
- Equipment and resource requirements necessary to operate and maintain facility; and
- Responsible party for operation and maintenance.

See Appendix D for additional Maintenance Plan requirements and suggested template.

Maintenance Activities

The following activities are recommended to properly maintain Detention Basin/Sand Filters:

- Inspect the detention basin a minimum of twice per year, before and after the rainy season, after large storm events, or more frequently, if needed. Some important items to check include: differential settlement, cracking, erosion, leakage, tree growth on the embankment, presence of burrows, the condition of the riprap in the inlet, outlet, and pilot channels, sediment accumulation in the basin, and the health and density of the vegetation on the basin side slopes and floor. Correct observed problems as necessary.
- Remove litter and debris from the banks and basin bottom as required.
- Check infiltration rate of the sand bed twice semiannually, once after significant rainfall.
- Scarify top three to five inches of filter surface by raking annually, or as necessary, to restore the infiltration rate of the filter.
- Inspect outlet for clogging a minimum of twice a year, before and after the rainy season, after large storms, and more frequently if needed.

Description

Porous Pavement Detention consists of an installation of Modular Block Porous pavement that is flat in all directions and is provided with a two-inch deep surcharge zone to temporarily store the SQDV draining from an adjacent area. Stormwater runoff infiltrates into the porous pavement and its sublayers of sand and gravel and slowly exits through an underdrain.

Modular Block Porous Pavement pavement consists of open void concrete block units laid upon a two-layer sand and gravel subgrade. The surface pavement voids are filled with sand. An alternative approach is to use stabilized grass porous pavement, consisting of grass turf reinforced with plastic rings and filter fabric underlain by gravel. A typical cross section of a Porous Pavement Detention system is shown in Figure 5-12.

A typical cross section of a porous pavement detention system is shown in Figure 5-12.

General Application

Porous Pavement Detention may be used in low vehicle-movement zones such as residential driveways and is often used as a parking lot pad surface. Although Porous Pavement Detention is typically used as parking pads in a parking lot, there are other potential applications such as low vehicle movement airport zones, parking aprons and maintenance roads, crossover/emergency stopping/parking lanes on divided highways, residential street parking lanes, residential driveways, maintenance roads and trails, and emergency vehicle and fire access lanes in apartment/multi-family/complex situations. Vehicle movement lanes that lead up to the porous pavement parking pads should be solid asphalt or concrete pavement. Grass can be used in the block voids, but it may require irrigation and lawn care.

Porous pavement detention should only be installed on flat surfaces. The pavements may be installed without free draining subsoils when provided with underdrains. In cases when the subsoils are not free draining, an impermeable liner should be provided to contain the water in the gravel pack and to mitigate concerns about expansive soils. The pavements should be located far enough from foundations in expansive soils so as to limit damage to potential structures. In addition, when a commercial or an industrial site may be handling chemicals and petroleum products that may spill to the ground, an impermeable liner with an underdrain is required to prevent groundwater and soil contamination.

Advantages

- Porous pavement detention basins can reduce flooding potential by infiltrating or slowing down runoff.
- Modular block patterns, colors, and materials can serve functional and aesthetic purposes.

Disadvantages

- The cost of porous pavement detention basins is high.

- The cost of restorative maintenance can be somewhat high when the system seals with sediment and can no longer function properly as a permeable pavement.
- The uneven driving surfaces and potential traps for the high heels of women's shoes are a potential problem.

Performance

Removal rates for both suspended sediment and associated constituents are projected to be high to moderate. Runoff through the sand and gravel of the modular block voids and entrapment in the gravel media are the primary removal mechanisms of pollutants. Removal rates for dissolved constituents are expected to be low to moderate.

Relative pollutant removal effectiveness of a porous pavement detention system is presented in Table 5-1.

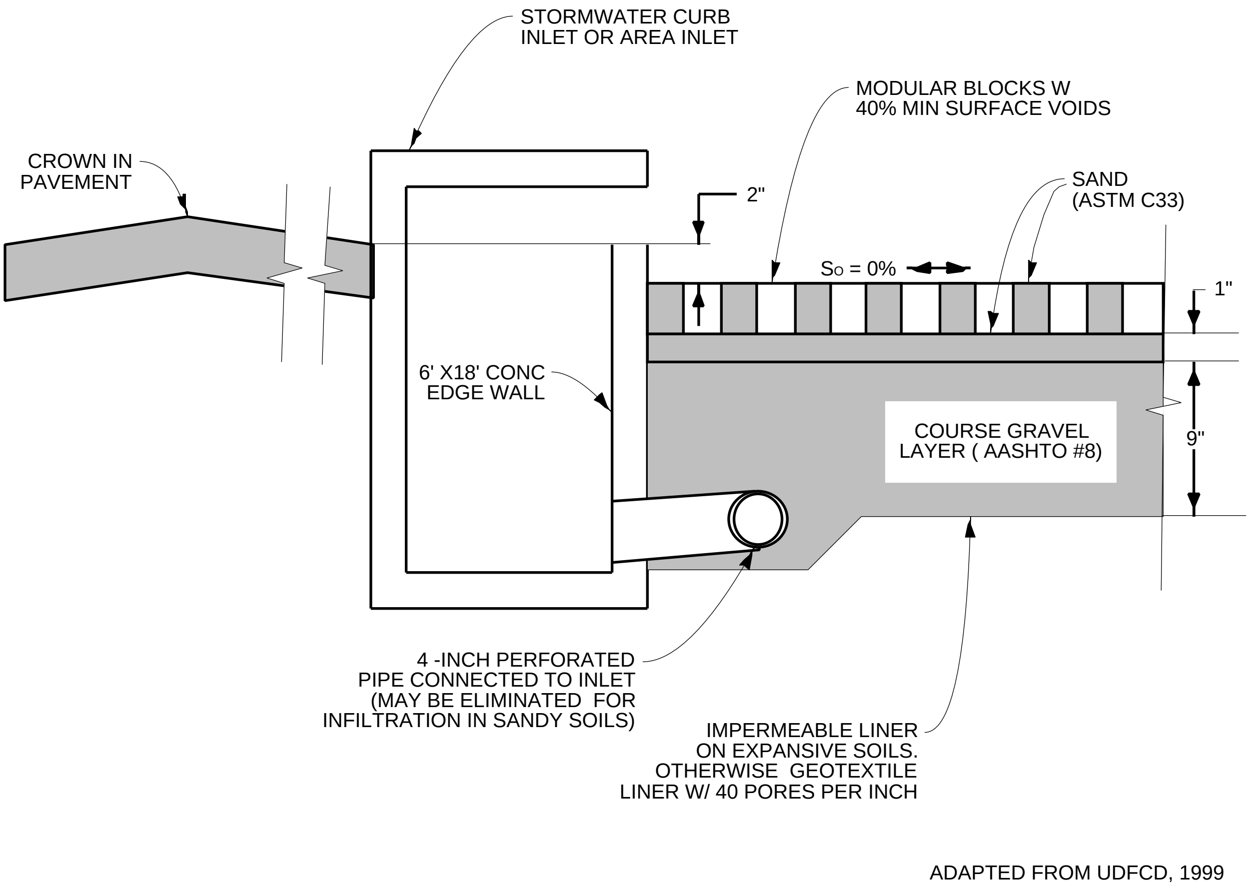

Figure 5-12. Porous Pavement Detention

Design Criteria and Procedure

Principal design criteria for porous pavement detention are listed in Table 5-11.

Table 5-11. Porous Pavement Detention Design Criteria

Design Parameter	Unit	Design Criteria
Drawdown time for SQDV	hrs	12 (minimum)
SQDV	ac-ft	80% annual capture. Use Figure 5-1 @ 12-hr drawdown
Modular Porous Block Type	%	40% surface area open
Porous Pavement Infill	--	ASTM C-33 Sand or equivalent
Base courses	–	1-in sand (ASTM C-33) over 9-in gravel
Perimeter Wall Width	in	6

Design procedure and application of design criteria are outlined in the following steps:

1. Basin Storage Volume — Provide a storage volume equal to 100 percent of the SQDV, based on a 12-hr drawdown time.

   a. Determine the percent imperviousness of the tributary area (I_a).

   b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate.

   c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 12-hr drawdown and I_{wq} value from step 1.b.

   d. Calculate the SQDV (ac-ft) as follows:

   $$SQDV = (V_u/2) \times Area$$

   where

   Area = Watershed area tributary to Porous Pavement Detention (acres)

2. Basin Surface Area — Calculate minimum required surface area based on surcharge depth of 2 inches as follows:

   $$\text{Surface Area} = SQDV\ (ft^3)/0.17\ (ft)$$

3. Select Block Type — Select appropriate modular blocks that have no less than 40 percent of the surface area open. The manufacturer's installation requirements shall be followed with the exception that porous

		pavement infill material requirements and base course dimension are adhered to.
4.	Porous Pavement Infill	The Modular Block Pavement openings should be filled with ASTM C-33 graded sand (fine concrete aggregate, not sandy loam turf).
5.	Base Courses	Provide 1-inch sand over 9-inch gravel base courses as shown in Figure 5-12.
6.	Perimeter Wall	Provide a concrete perimeter wall to confine the edges of the Porous Pavement Detention area. The wall should be minimum 6-inch wide and at least 6 inches deeper than all the porous media and modular block depth combined.
7.	Subbase	If expansive soils or rock are a concern or the tributary catchment has chemical or petroleum products handled or stored, install an impermeable membrane below the base course. Otherwise install a non-woven geotextile membrane to encourage filtration.
8.	Overflow	Provide an overflow, possibly with an inlet to a storm sewer, set at 2 inches above the level of the porous pavement surface. Make sure the 2-inch ponding depth is contained and does not flow out of the area at ends or sides.

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-7: Porous Pavement Detention

Designer:______________________________

Company:______________________________

Date:______________________________

Project:______________________________

Location:______________________________

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	100	%
b. Effective Imperviousness (Determine using Figure 3-4)	I_{wq} =	100	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 12-hr drawdown and I_{wq}	V_u=	0.34	in
d. Watershed Area Tributary to Porous Pavement Detention	Area =	0.1	ac
e. Calculate SQDV SQDV = $(V_u/12) \times$ Area	SQDV =	0.0028	ac-ft
1. Basin Surface Area			
a. Design Volume (SQDV)	SQDV =	125	ft^3
b. A_s = Design Volume/(0.17 ft) (based on surcharge depth of 2 in)	A_s	726	ft^2
2. Block Type	Block name:	Uni-Green	
	Manufacturer:	Pavestone	
a. Minimum open area = 40%	Open Area =	40	%
b. Minimum thickness = 4 in	Thickness	4.0	in
3. Base Course (Check)			
a. ASTM C33 Sand Layer (1 inch)	Sand Layer	X	
b. ASSHTO M43-No.8 Gravel Layer (9 inches)	Gravel Layer	X	

Notes:

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Maintenance Requirements

The following maintenance requirements apply to porous pavement detention:

Maintenance Agreement

On-site treatment control measures are maintained by the owner/operator. Maintenance agreements between the owner/operator and the City may be required. However, if pretreatment is recommended but not included in the design, a maintenance agreement will be required. If required, a maintenance agreement must be executed by the owner/operator before the improvement plans are approved. See Appendix C for example maintenance and access agreement.

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the City's request. The Maintenance Plan should address items such as:

- Operation plan and schedule, including a site map
- Maintenance and cleaning activities and schedule
- Equipment and resource requirements necessary to operate and maintain facility
- Responsible party for operation and maintenance

See Appendix D for additional Maintenance Plan requirements and suggested template.

Maintenance Activities

The following activities are recommended to properly maintain Porous Pavement Detention:

- Inspect pavements at least semiannually during storm events to determine if runoff is infiltrating properly.
- If infiltration is significantly reduced, remove surface sand by vacuuming. Dispose and replace old sand with fresh sand.
- Remove litter and debris from the pavement area as required.

Description

Porous Landscape Detention functions similarly to Porous Pavement Detention except that vegetation is used instead of porous blocks. A Porous Landscape Detention system consists of a low-lying vegetated area underlain by a sand bed with an underdrain pipe. A shallow surcharge zone is provided above the basin for temporary storage of the SQDV. During stormwater events, runoff accumulates in the vegetated zone and gradually infiltrates into the underlying sand bed, filling the void spaces of the sand. The underdrain gradually dewaters the sand bed and discharges the runoff to downstream conveyance. Like porous pavement detention, Porous Landscape Detention allows for the detention of the SQDV to be provided on sites with limited open area available for stormwater detention.

A typical cross section of porous landscape detention is shown in Figure 5-13.

General Application

A Porous Landscape Detention facility can be located in almost any open areas of a site. It is ideally suited for small installments such as parking lot islands, street medians, roadside swale features, and site entrance or buffer features. The facility can be implemented on a larger scale, serving as an infiltration basin/sand filter for an entire site, if desired, provided the stormwater quality capture volume and average depth requirements are met.

If an underdrain system is incorporated into the design, the measure is suited for almost any site regardless of soil type. An underdrain ensures the drainage of the subgrade whenever subsoils are not free draining. If sandy soils (types A or B) are present, which is not a requirement; the facility can be installed without an underdrain. In cases where the subsoils are not free draining, an impermeable liner should be provided to contain the water in the subgrade and to mitigate concerns about expansive soils. This treatment control requires a relatively flat surface area and may be difficult to incorporate into steeply sloping terrain.

The facility should be located far enough from foundations in expansive soils so as to limit damage to potential structures. In addition, when a commercial or an industrial site may be handling chemicals and petroleum products that may spill to the ground, an impermeable liner with an underdrain is required to prevent groundwater and soil contamination.

Advantages

- Porous Landscape Detention provides stormwater capture on a site while reducing the impact on developable land.
- Porous Landscape Detention can reduce flooding potential by infiltrating or slowing down runoff.
- Porous Landscape Detention provides a natural moisture source for vegetation, which enabling “green areas” to exist with reduced irrigation

Disadvantages

- The sand and gravel sublayers are prone to clogging from sediment loading.
- The cost of restorative maintenance can be high when the system seals with sediment and can no longer function as a stormwater basin.
- A Porous Landscape Detention system should be placed away from building foundations or other areas where expansive soils are present, although an impermeable layer or underdrain can mitigate some of these concerns.

Performance

The degree of pollutant removal by Porous Landscape Detention should be significant and should equal or exceed the removal effectiveness provided by sand filters. In addition to removal by settling, Porous Landscape Detention basins provide filtering, adsorption, and biological uptake of constituents in stormwater. Relative pollutant removal effectiveness is indicated in Table 5-1.

Design Criteria and Procedure

Principal design criteria for Porous Landscape Detention are listed in Table 5-12.

Table 5-12. Porous Landscape Detention Design Criteria

Design Parameter	Unit	Design Criteria
Drawdown time for SQDV	hrs	12 hrs
SQDV	ac-ft	80% annual capture. Use Figure 5-1 @ 12-hr drawdown
Average surcharge depth	in	6-12
Sand-peat layer	in	18 (minimum) – 75% ASTM C-33 Sand + 25% peat
Gravel layer	in	9 – ASSHTO #8 Coarse Aggregate
Vegetative (sandy loam turf) layer	in	6

When implementing multiple small Porous Landscape Detention systems on a site, it is increasingly important to accurately account for each upstream drainage area tributary to each Porous Landscape Detention site to make sure that each facility is properly sized, and that all portions of the development site are directed to porous landscape detention.

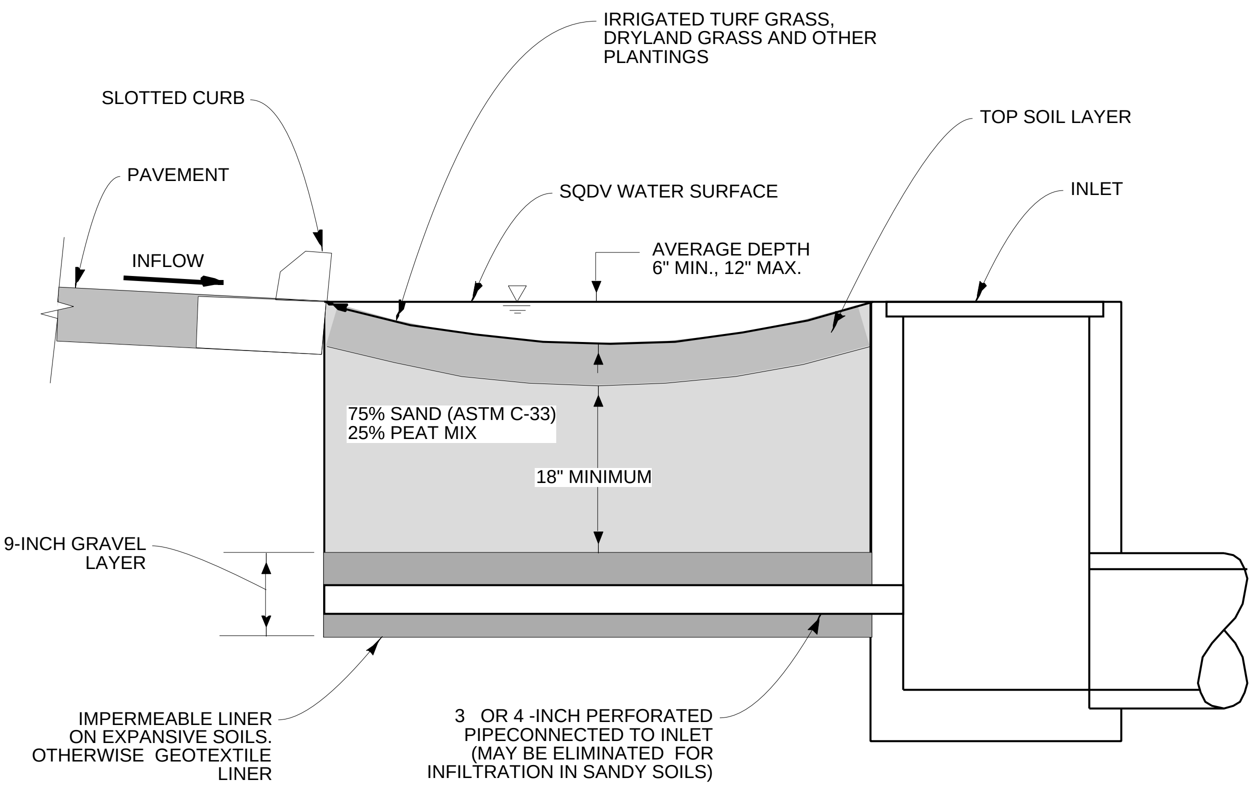

Figure 5-13. Porous Landscape Detention

Design procedure and application of design criteria are outlined in the following steps:

1. Basin Storage Volume — Provide a storage volume equal to 100 percent of the SQDV, based on a 12-hr drawdown time.

   a. Determine the percent imperviousness of the tributary area (I_a).

   b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate.

   c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 12-hr drawdown and I_{wq} value from step 1.b.

   d. Calculate the SQDV in acre-ft as follows:

   $$SQDV = (V_u/12) \times Area$$

   where

   Area = Watershed area tributary to PLD (ac)

2. Basin Surface Area — Calculate minimum required surface area as follows:

   $$\text{Surface Area} = \text{SQDV/average surcharge depth}$$

3. Base Courses — Provide 18-inch sand + peat layer over 9-inch gravel layer as shown in Figure 5-13. Thoroughly mix 75% sand (ASTM C-33) with 25% peat for filtration and adsorption of contaminants.

4. Subbase — If expansive soils or rock are a concern or the tributary catchment has chemical or petroleum products handled or stored, install an impermeable membrane below the base course. Otherwise install a non-woven geotextile membrane to encourage filtration.

5. Surcharge Depth — Maintain the average SQDV depth between 6 and 12 inches. Average depth is defined as water volume divided by the water surface area.

6. Vegetative Layer — Provide a sandy loam turf layer above the sand-peat mix layer. This layer shall be no less than 6 inches thick, but a thicker layer is recommended to promote healthier vegetation.

7. Overflow — Provide an overflow, possibly with an inlet to a storm sewer, set above the SQDV surcharge water level

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-8: Porous Landscape Detention

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	100	%
b. Effective Imperviousness (Determine using Figure 3-4)	I_{wq} =	100	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 12-hr drawdown and I_{wq}	V_u=	0.34	in
d. Watershed Area Tributary to Porous Landscape Detention	Area =	0.25	ac
e. Calculate SQDV SQDV = (V_u/12) × Area	SQDV =	0.007	ac-ft
2. Basin Surface Area			
a. Design Volume (SQDV)	SQDV =	308	ft^3
b. Average Depth	Average Depth =	1.0	ft
c. A_s = Design Volume/Average Depth	A_s =	306	ft^2
3. Base Course Layers (check)	Sandy Loam Turf	X	in (6-in min.)
	Sand/peat mix	X	in (18-in min.)
	Gravel	X	in (9-in min.)
4. Subsurface Drainage (check)	X	Infiltration to subgrade with permeable geotextile membrane	
	____	Underdrain with impermeable membrane	
	____	Underdrain with permeable goetextile membrane	

Notes:

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Maintenance Requirements

The following maintenance requirements apply to porous landscape detention:

Maintenance Agreement

On-site treatment control measures are maintained by the owner/operator. Maintenance agreements between the owner/operator and the City may be required. However, if pretreatment is recommended but not included in the design, a maintenance agreement will be required. If required, a maintenance agreement must be executed by the owner/operator before the improvement plans are approved. See Appendix C for example maintenance and access agreement.

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the City's request. The Maintenance Plan should address items such as:

- Operation plan and schedule, including a site map
- Maintenance and cleaning activities and schedule
- Equipment and resource requirements necessary to operate and maintain facility
- Responsible party for operation and maintenance

See Appendix D for additional Maintenance Plan requirements and suggested template.

Maintenance Activities

The following activities are recommended to properly maintain Porous Landscape Detention:

- Mow grass and remove weeds to limit unwanted vegetation as required. Maintain irrigated turf grass height at two to four inches and non-irrigated native grasses at four to six inches.
- Remove litter and debris from landscape area as required.
- Inspect the Porous Landscape Detention facility at least twice per year during storm events to determine if runoff is infiltrating properly.
- If infiltration is significantly reduced, remove and replace sand loam turf and landscaping layer. This may be required every five to ten years, or more frequently, depending on sediment loads.

Description

An Infiltration Basin is a shallow earthen basin constructed in naturally pervious soils (type A or B) designed for infiltrating stormwater. An Infiltration Basin functions by retaining the SQDV and allowing the retained runoff to percolate into the underlying native soils and into the groundwater table over a specified period of time. The bottoms of the basins are typically vegetated with dry-land grasses or irrigated turf grass.

A typical layout of an Infiltration Basin is shown in Figure 5-14.

General Application

Infiltration basins can serve drainage areas of up to 50 acres. Infiltration basins can be sized to treat storm volumes greater than the SQDV. However, treatment efficiencies are reduced and the threat of system failure increases as the volume of runoff directed to the Infiltration Basin increases above the SQDV. It is recommended that the basin be sized to treat the storm quality capture volume only and divert all other flows around the treatment control measure.

Before exploring the use of infiltration controls, preliminary soil investigations, including a percolation test, is required to assess whether the soils on site have adequate infiltration rates. Infiltration basins should not be placed in high-risk areas such as service/gas stations, truck stops, and heavy industrial sites due to groundwater contamination risk. Tributary areas should have a low potential for erosion. Other suitability considerations include soil makeup, site topography, and the location of other facilities.

Groundwater separation between the bottom of the basin and the groundwater table should be at least 10 feet to allow for sufficient treatment to prevent groundwater contamination. Additionally, sites constructed of fill, having a base flow, or having a slope greater than 15 percent should not be considered for Infiltration Basin use. Adequate head must be available to operate flow splitting structures to prevent ponding and backwater. Siting of infiltration basins must follow Department of Health Services requirements if they are placed near surface or groundwater supplies.

Advantages

- Infiltration basins can also control runoff volume, which may reduce downstream bank erosion in watercourses.
- A grass-covered area in a park could function as an Infiltration Basin during the wet season and as a park during the dry season.
- Infiltration basins provide up to 100 percent reduction in the load discharged to surface waters.

Disadvantages

- The potential for clogging by sediments is a significant concern for infiltration basins. Studies have shown relatively high failure rates compared with other management practices.

- The cost of restorative maintenance can be high if the soil infiltration rates are significantly reduced due to sediment deposition.
- There is a risk of groundwater contamination in very coarse soils since coarse soils do not effectively remove dissolved pollutants.
- May not be appropriate for industrial sites or locations where spills may occur.
- Infiltration basins require a minimum soil infiltration rate of 0.5 inches/hour, not appropriate at sites with Hydrologic Soil Types C and D.
- If infiltration rates exceed 2.4 inches/hour, then the runoff should be fully treated prior to infiltration to protect groundwater quality.

Performance

As water migrates through porous soil and rock, pollutant attenuation mechanisms include precipitation, sorption, physical filtration, and bacterial degradation. Actual pollutant removal in the subsurface would be expected to vary depending upon site-specific soil types. This technology eliminates discharge to surface waters except for the very largest storms and complete removal of all stormwater constituents can be assumed. Relative pollutant removal effectiveness is indicated in Table 5-1.

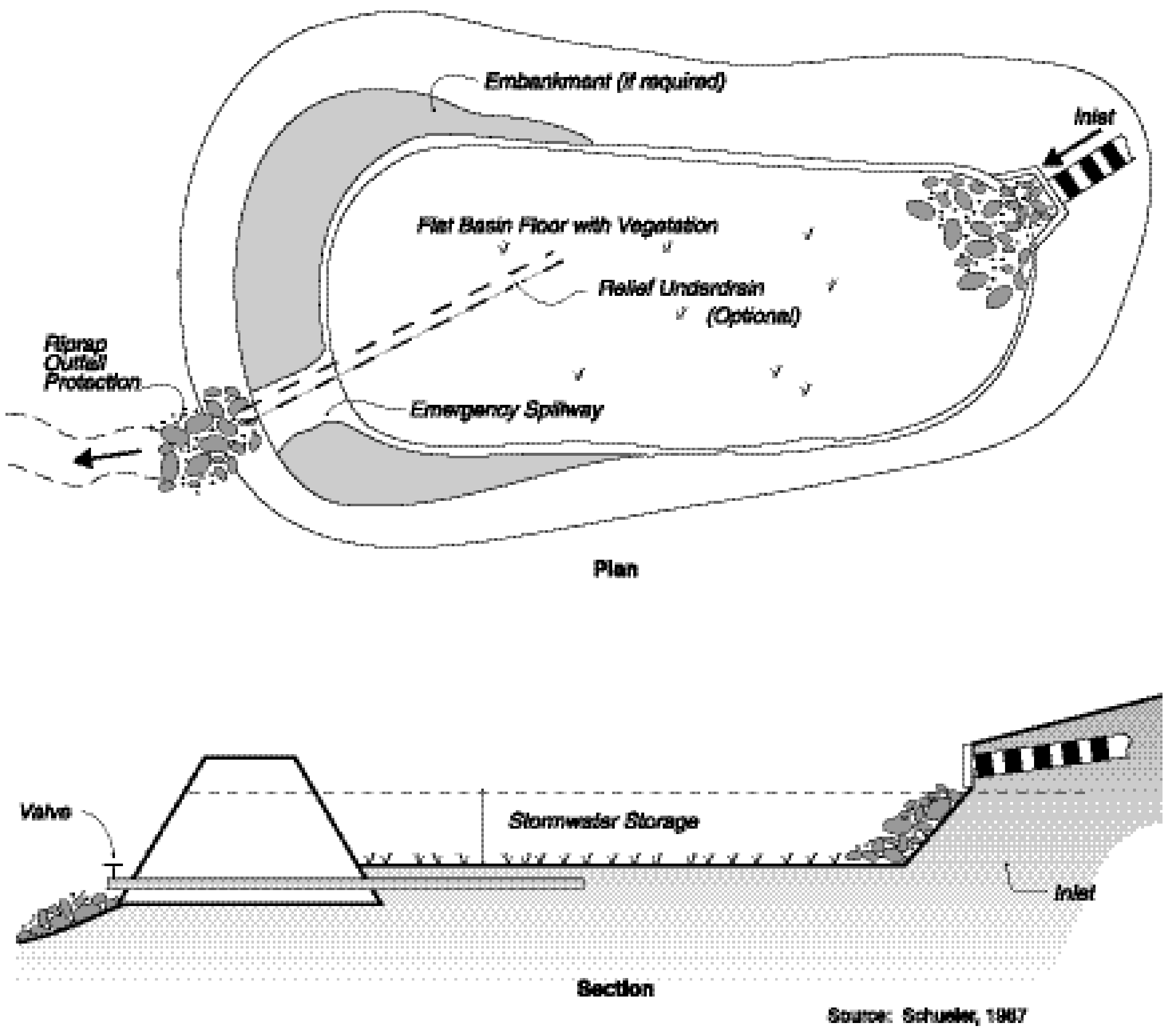

Figure 5-14. Infiltration Basin

Design Criteria and Procedure

Principal design criteria for infiltration basins are listed in Table 5-13.

Table 5-13. Infiltration Basin Design Criteria

Design Parameter	Unit	Design Criteria
Drawdown time for SQDV	hrs	40
SQDV	ac-ft	80% annual capture. Use Figure 5-1 @ 40-hr drawdown
Bottom Basin Elevation	ft	10 ft above seasonally high groundwater table minimum.
Freeboard (minimum)	ft	1.0
Setbacks	ft ft	100 ft from wells, tanks, fields, springs 20 ft down slope or 100 ft up slope from foundations
Inlet/outlet erosion control	–	Energy dissipater to reduce inlet/outlet velocity
Embankment side slope (H:V)	–	≥ 4:1 inside/ ≥3:1 outside (without retaining walls)
Maintenance access ramp slope (H:V)	hrs	10:1 or flatter
Maintenance access ramp width	ft	16.0 – approach paved with asphalt concrete
Vegetation	–	Side slopes and bottom (may require irrigation during summer)

Design procedure and application of design criteria are outlined in the following steps:

1. Basin Storage Volume — Provide a storage volume equal to 100 percent of the SQDV, based on a 40-hr drawdown time.

   a. Determine the percent imperviousness of the tributary area (I_a).

   b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate.

   c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 40-hr drawdown and I_{wq} value from step 1.b.

   d. Calculate the SQDV in acre-ft as follows:

   $$SQDV = (V_u/12) \times Area$$

   where

   Area = Watershed area tributary to Infiltration Basin (ac)

2. Basin Surface Area — Calculate the minimum surface area of the infiltration system:

$$A_m = V/D_m$$

where

A_m = minimum area required (ft^2)

V = volume of the Infiltration Basin (ft^3)

D_m = maximum allowable depth (ft)

where

$$D_m = t \times I/12s$$

and

I = Site infiltration rate (in/hr)

s = Safety factor

t = Minimum drawdown time = 40 hrs

In the formula for maximum allowable depth, the safety factor accounts for the possibility of inaccuracy in the infiltration rate measurement. The less certain the infiltration rate the higher the safety factor shall be. Minimum safety factors shall be as follows:

- Without site-specific borings and percolation tests, use s=10
- With borings (but no percolation test), use s=6
- With percolation test (but no borings), use s=5
- With borings and percolation test, use s=3

3. Inline/Offline

Basins may be on-line or off-line with flood control facilities, although off-line basins are recommended. For on-line basins, the water quality outlet may be superimposed on the flood control outlet or may be constructed as a separate outlet.

4. Vegetation

Bottom vegetation provides erosion protection and sediment entrapment. Basin bottoms, berms, and side slopes may be planted with native grasses or with irrigated turf.

5. Embankments

Design embankments to conform to requirements of the State of California Division of Safety of Dams, if the basin dimensions cause it to fall under that agency's jurisdiction. Interior slopes should be no steeper than 4:1 and exterior slopes no steeper than 3:1. Flatter slopes are preferable.

6. Access

All-weather access to the bottom, forebay, and outlet works shall be provided for maintenance vehicles. Maximum grades of access ramps should be 10 percent and minimum width should be 16 feet. Ramps should be paved with concrete. Provide security fencing, except when used as a recreation area.

7. Bypass — Provide for bypass or overflow of runoff volumes in excess of the SQDV. Spillway and overflow structures should be designed in accordance with applicable standards of the City.

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-9: Infiltration Basin

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	100	%
b. Effective Imperviousness (Determine using Figure 3-4)	I_{wq} =	100	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40-hr drawdown and I_{wq}	V_u=	0.60	in
d. Watershed Area Tributary to Infiltration Basin	Area =	0.2	ac
e. Calculate SQDV SQDV = (V_u/12) × Area	SQDV =	0.010	ac-ft
2. Maximum Allowable Depth ($D_m = t \times I/12s$)			
a. Site infiltration rate (I)	I =	2.0	in/hr
b. minimum drawdown time (t = 40 hrs)	t =	40	hrs
c. safety factor (s)	s =	3	
d. $D_m = t \times I/12s$	D_m =	2.22	ft
3. Basin Surface Area A_m = SQDV/D_m	A_m =	196	ft^2
4. Vegetation (Check type used or describe "Other")	_X_ Native Grasses ____ Irrigated Turf Grass ____ Other		

Notes:

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Maintenance Requirements

The following maintenance requirements apply to infiltration basins:

Maintenance Agreement

On-site treatment control measures are maintained by the owner/operator. Maintenance agreements between the owner/operator and the City may be required. However, if pretreatment is recommended but not included in the design, a maintenance agreement will be required. If required, a maintenance agreement must be executed by the owner/operator before the improvement plans are approved. See Appendix C for example maintenance and access agreement.

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the City's request. The Maintenance Plan should address items such as:

- Operation plan and schedule, including a site map;
- Maintenance and cleaning activities and schedule;
- Equipment and resource requirements necessary to operate and maintain facility; and
- Responsible party for operation and maintenance.

See Appendix D for additional Maintenance Plan requirements and suggested template.

Maintenance Activities

The following activities are recommended to properly maintain Infiltration Basins:

- Clean when loss of infiltrative capacity is observed. If drawdown time is observed to have increased significantly over the design drawdown time, removal of sediment may be necessary. This is an expensive maintenance activity and the need for it can be minimized through prevention of upstream erosion.
- Trim vegetation at the beginning and end of the wet season to prevent the establishment of woody vegetation and for aesthetic and vector control reason. Monitor health of vegetation and replace, as necessary.
- Remove litter and debris from Infiltration Basin area.
- Schedule semiannual inspections for beginning and end of the wet season to identify potential problems such as erosion of the basin side slopes and invert, standing water, trash and debris, and sediment accumulation.
- Inspect for standing water at the end of the wet season and control mosquitoes, as needed.
- Remove accumulated sediment and re-grade when the accumulated sediment volume exceeds 10 percent of the basin.
- If erosion is occurring within the basin, re-vegetate immediately and stabilize with erosion control mulch or mat until vegetation cover is established.
- To avoid reversing soil development, scarification or other disturbance should only be performed when there are actual signs of clogging rather than on a routine basis.

Infiltration Trench

Description

An Infiltration Trench is a long, narrow, trench constructed in naturally pervious soils (type A or B) and filled with subsurface gravel and sand. Runoff is stored in the trench until it infiltrates into the soil profile. Overflow drains are often provided to provide drainage if the trench becomes clogged. The trench is designed to retain and infiltrate the SQDV over a specified period of time. Infiltration Trenches perform well for the removal of fine sediment and associated pollutants. Upstream control measures such as vegetated buffer strips, or vegetated swales, are typically used to limit amounts of coarse sediment entering the trench.

Typical elements of an Infiltration Trench system are shown in Figure 5-15. Infiltration vaults and leach fields are variations of the infiltration trench concept in which runoff is distributed to upper zone of the subsurface gravel bed by means of perforated pipes. Illustrations of infiltration vaults and leach fields are shown in Figure 5-16 and 5-17, respectively.

General Application

Infiltration Trenches can generally serve drainage areas less than ten acres and are usually combined with upstream treatment control measures to reduce sediment load. Infiltration Trenches are easily incorporated into the landscape feature of development sites. The use of Infiltration Trenches may be limited by a number of factors, including the type of native soils, climate, and depth of the groundwater table. Tributary areas should have a low potential for erosion. An Infiltration Trench is not suitable for sites that use or store chemicals or hazardous materials unless hazardous and toxic materials are prevented from entering the trench.

Before exploring the use of infiltration controls, preliminary soil investigations, including a percolation test, is required to assess whether the soils on site have adequate infiltration rates. Soil types A, B, and C should only be considered as viable sites. The soil should not have more than 30 percent clay or more than 40 percent clay and silt combined.

Groundwater separation between the bottom of the trench and the groundwater table should be at least 10 feet to allow for sufficient treatment to prevent groundwater contamination. Additionally, sites constructed on fill, having a base flow, or having a slope greater than 15 percent should not be considered for Infiltration Trench use. Adequate head must be available to operate flow splitting structures to prevent ponding and backwater. Siting for Infiltration Trenches must follow Department of Health Services requirements if they are placed near surface or groundwater supplies.

Advantages

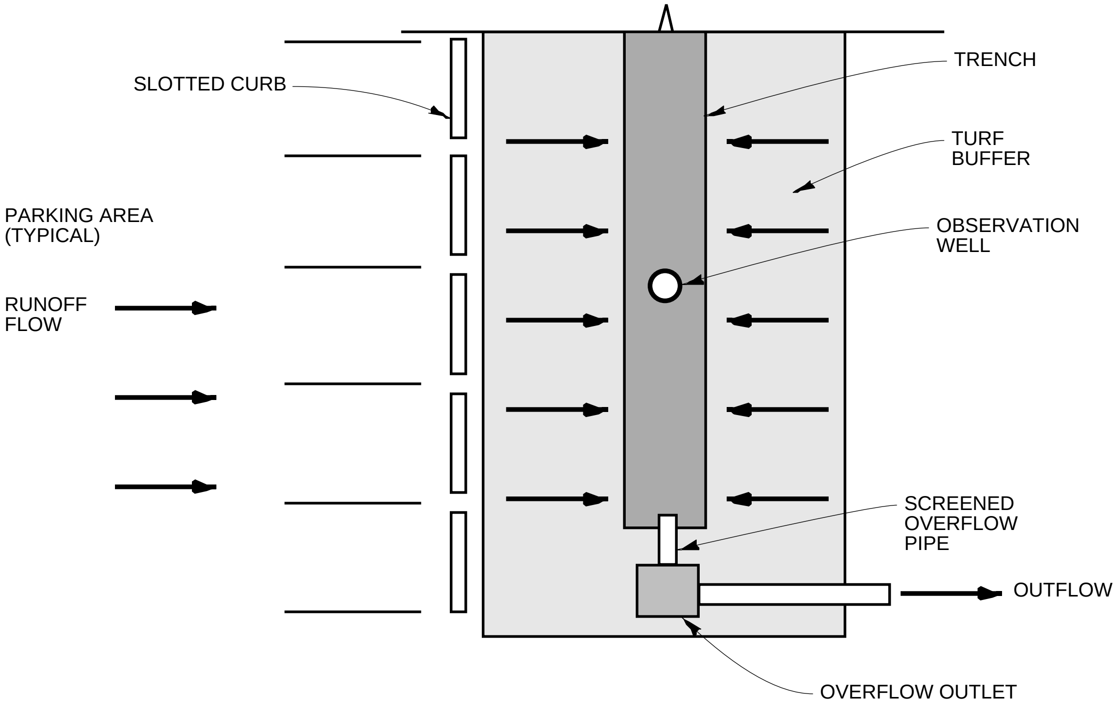
- Infiltration Trenches can control runoff volume, which may reduce downstream bank erosion in watercourses.
- Infiltration Trenches provide 100% reduction in the load discharged to surface waters.
- As an underground BMP, trenches are unobtrusive and have little impact of site aesthetics.

Disadvantages

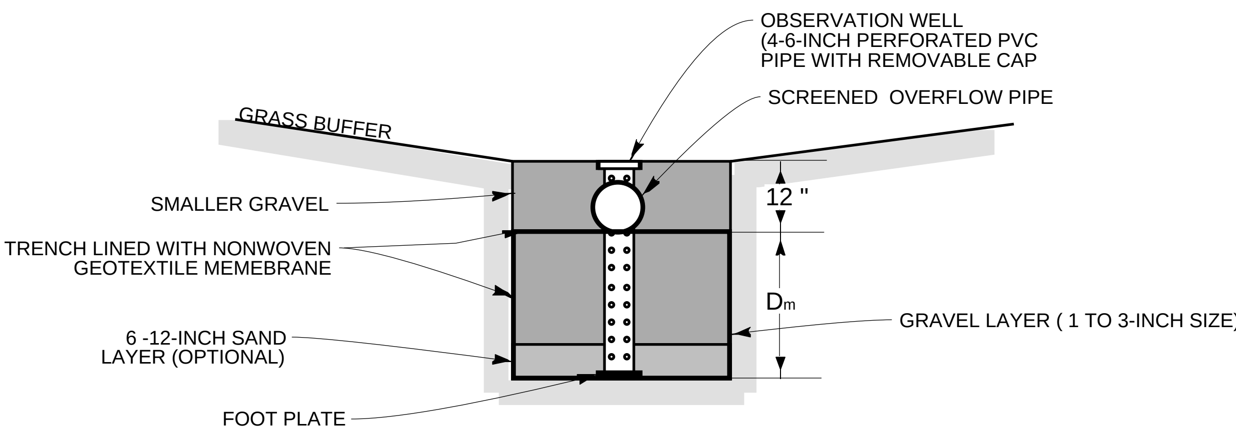
- The potential for clogging by sediments is a significant concern for Infiltration Trenches.
- The cost of restorative maintenance can be high if the soil infiltration rates are significantly reduced due to sediment deposition.
- There is a risk of groundwater contamination in very coarse soils since coarse soils do not effectively remove dissolved pollutants.
- May not be appropriate for industrial sites or locations where spills may occur.
- If infiltration rates exceed 2.4 inches/hour, then the runoff should be fully treated prior to infiltration to protect groundwater quality.

Performance

Infiltration trenches can be expected to remove up to 90 percent of sediments, metals, coliform bacteria, and organic matter, and up to 60 percent of phosphorus and nitrogen in the infiltrated runoff. Biochemical oxygen demand (BOD) removal is estimated to be between 70 to 80 percent. Lower removal rates for nitrates, chlorides, and soluble metals should be expected, especially in sandy soils. Pollutant removal efficiencies may be improved by using washed aggregate and adding organic matter and loam to the subsoil. The stone aggregate should be washed to remove dirt and fine particles before placement in the trench. The addition of organic material and loam to the trench subsoil may enhance metals removal through adsorption. This technology also decreases discharge to surface waters except for the very largest storms. Relative pollutant removal effectiveness is indicated in Table 5-1.



PLAN VIEW



SECTION VIEW

Figure 5-15. Infiltration Trench

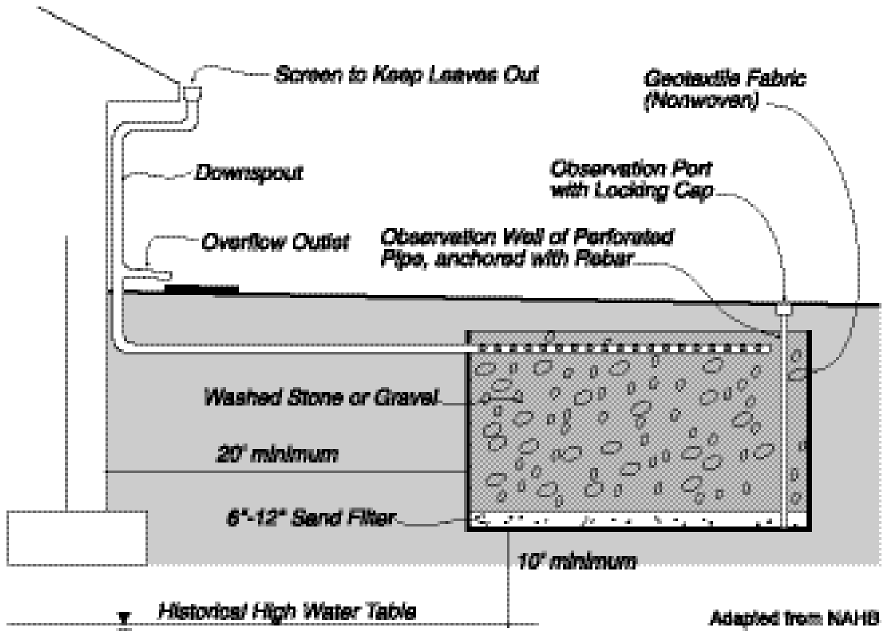


Figure 5-16. Infiltration Vault

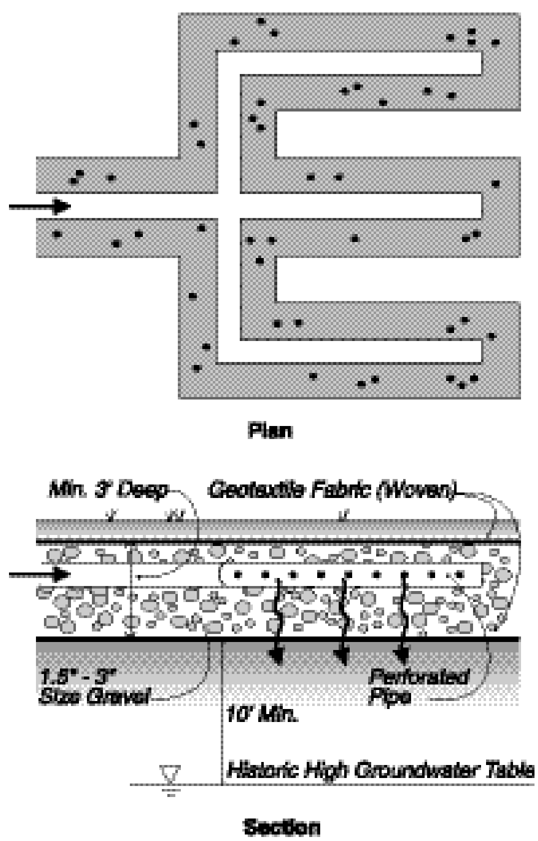


Figure 5-17. Leach Field

Design Criteria and Procedure

Principal design criteria for infiltration trenches are listed in Table 5-14. These criteria also apply to vaults and leach fields

Table 5-14. Infiltration Trench Design Criteria

Design Parameter	Unit	Design Criteria
Drawdown time for SQDV	hrs	40
SQDV	ac-ft	80% annual capture. Use Figure 5-1 @ 40-hr drawdown
Trench bottom elevation	ft	5 ft above seasonally high groundwater table minimum.
Trench surcharge depth (D_m)	ft	$D_m \leq 8.0$ ft
Gravel bed material	in	Clean, washed aggregate 1 to 3 (diameter)
Trench lining material	–	Geotextile fabric (see Table 5-7)
Setbacks	ft ft	100 ft from wells, tanks, fields, springs 20 ft down slope or 100 ft up slope from foundations Do not locate under tree drip-lines

Design procedure and application of design criteria are outlined in the following steps:

1. Trench Storage Volume — Provide a storage volume equal to 100 percent of the SQDV, based on a 40-hr drawdown time.

   a. Determine the percent imperviousness of the tributary area (I_a).

   b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate.

   c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 40-hr drawdown and I_{wq} value from step 1.b.

   d. Calculate the SQDV (acre-ft) as follows:

   $$SQDV = (V_u/12) \times Area$$

   where

   Area = Watershed area tributary to infiltration trench (ac)

2. Trench Water Depth — Calculate the maximum allowable depth of water surcharge in the trench. Maximum depth should not exceed 8 feet.

   $$D_m = t \times I/12s$$

   where

   I = Site infiltration rate (in/hr)

s = Safety factor

t = Minimum drawdown time = 40 hours

In the formula for maximum allowable depth, the safety factor accounts for the possibility of inaccuracy in the infiltration rate measurement. The less certain the infiltration rate the higher the safety factor shall be. Minimum safety factors shall be as follows:

- Without site-specific borings and percolation tests, use s=10
- With borings (but no percolation test), use s=6
- With percolation test (but no borings), use s=5
- With borings and percolation test, use s=3

3. Trench Surface Area

Calculate the minimum surface area of the trench bottom:

$$A_m = V/D_m$$

where

A_m = Minimum area required (ft^2)

V = SQDV (ft^3)

D_m = Maximum allowable depth (ft)

4. Observation Well

Provide a vertical section of perforated PVC pipe, 4 to 6 inches in diameter, installed flush with top of trench on a foot plate and with a locking, removable cap.

5. Bypass

Provide for bypass or overflow of runoff volumes in excess of the SQDV by means of a screened overflow pipe connected to downstream storm drainage or grated overflow outlet.

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-10: Infiltration Trench

Designer:____________________

Company:____________________

Date:____________________

Project:____________________

Location:____________________

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	70	%
b. Effective Imperviousness (Determine using Figure 3-4)	I_{wq} =	66	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40-hr drawdown and I_{wq}	V_u=	0.44	in
d. Watershed Area Tributary to Infiltration Trench	Area =	0.5	ac
e. Calculate SQDV SQDV = (V_u/12) × Area	SQDV =	0.018	ac-ft
2. Maximum Allowable Depth ($D_m = t \times I/12s$)			
a. Site infiltration rate (I)	I =	3.0	in/hr
b. minimum drawdown time (t = 40 hrs)	t =	40	hrs
c. safety factor (s)	s =	3	
d. $D_m = t \times I/12s$	D_m =	3.33	ft
3. Trench Bottom Surface Area			
$A_s = SQDV/D_m$	A_s =	240	ft^2

Notes:

Maintenance Requirements

The following maintenance requirements apply to infiltration trenches:

Maintenance Agreement

On-site treatment control measures are maintained by the owner/operator. Maintenance agreements between the owner/operator and the City may be required. However, if pretreatment is recommended but not included in the design, a maintenance agreement will be required. If required, a maintenance agreement must be executed by the owner/operator before the improvement plans are approved. See Appendix C for example maintenance and access agreement.

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the City's request. The Maintenance Plan should address items such as:

- Operation plan and schedule, including a site map
- Maintenance and cleaning activities and schedule
- Equipment and resource requirements necessary to operate and maintain facility
- Responsible party for operation and maintenance

See Appendix D for additional Maintenance Plan requirements and suggested template.

Maintenance Activities

Infiltration trenches typically require less maintenance than other control measures. Recommended maintenance activities include:

- Schedule semiannual inspections for beginning and end of the wet season to identify potential problems such as erosion of the basin side slopes and invert, standing water, trash and debris, and sediment accumulation.
- Clean when loss of infiltrative capacity is observed. If drawdown time is observed to have increased significantly over the design drawdown time, removal of sediment may be necessary. This is an expensive maintenance activity and the need for it can be minimized through prevention of upstream erosion.
- Trim vegetation at the beginning and end of the wet season to prevent the establishment of woody vegetation and for aesthetic and vector control reason. Monitor health of vegetation and replace, as necessary.
- Inspect for standing water at the end of the wet season and control mosquitoes, as needed.
- Remove litter and debris from infiltration trench area.
- If erosion is occurring within the tributary area, revegetate immediately and stabilize with erosion control mulch or mat until vegetation cover is established.

Description

A media filter is a two-stage constructed treatment system including a pretreatment settling basin and a filter bed containing sand or other absorptive filtering media. The filter bed is supported by a gravel base course and is underdrained with perforated pipe. As stormwater flows into the system, large particles settle out in the first chamber and finer particles and other pollutants are removed in the filter chamber. Due to size constraints, media filters are designed to only treat the SQDV.

This section provides design information for three types of media filters, each named after the area of the country where they were developed:

- T11.1: Austin Sand Filter System – large units, above or below surface, used in large drainage areas (up to 50 acres).
- T-11.2: DC Underground Sand Filter – underground line system used for small drainage areas (up to 1.5 acres); receives concentrated flows.
- T-11.3: Delaware (Linear) Sand Filter - situated along perimeter of small drainage area (up to 5 acres); receives sheet or concentration flows; can be used in areas of high ground water.

Due to size constraints, media filters are designed to only treat the SQDV. Diversion structures are used to route storm volumes in excess of the SQDV around the filter (see Appendix B).

General Application

Media filters are generally suited for sites where there is no base flow and the sediment load is relatively low. Media filters remove particulate and floatable materials and are appropriate for drainage areas of up to 100 acres. The filters are well-suited for drier areas and/or urban areas because they do not require vegetation and require less space than other treatment controls. Land use for which media filters are appropriate include residential, commercial, institutional, and industrial, except for extractive, chemical/petroleum, food and printing. A media filter is not appropriate for agricultural sites or other areas with expanses of erosive soil upstream of the unit.

Selection of a unit configuration for a media filter depends on the size of the drainage area and the facility location. For large watersheds (i.e. up to 50 acres), an Austin sand filter is recommended. For small catchments requiring underground facilities, a DC sand filter is recommended. Delaware sand filters are especially suitable for paved sites and industrial sites because they can be situated to accept sheet flow from adjacent pavement.

Since an underdrain system is incorporated into its design, media filters are suited for most soil conditions and the presence of sandy soils is not a requirement. The treatment system has a relatively flat surface area and requires near-zero slope terrain. However, it is challenging to use most sand filters on flat surfaces because they require a significant amount of hydraulic head (about four feet) to allow flow through the system. One exception is the perimeter sand filter, which can be applied with as little as two feet of head.

Sand filters are preferred over infiltration practices when contamination of groundwater with conventional pollutants is of concern. This usually occurs in areas where underlying soils alone cannot treat runoff adequately or groundwater tables are high. In most cases, sand filters can be constructed with impermeable basin or chamber bottoms, which help to collect, treat, and release runoff to a storm drainage system or directly to surface water with no contact between contaminated runoff and groundwater.

Advantages

- Media filters provide effective water quality enhancement through settling and filtering while requiring little space and can be placed underground.
- Media filters may be used when there is a lack of water for irrigation or base flow.
- Widespread application with sufficient capture volume can provide significant control of channel erosion and enlargement caused by changes to stormwater flow.

Disadvantages

- Clogging is a significant problem for media filters. This can be countered by using upstream treatment controls that effectively remove large sediment.
- Significant head loss may limit use on flat surfaces.
- Media filters are more expensive to construct than many other treatment controls.
- Media filters may require more maintenance depending upon the sizing of the filter bed.
- Media filters work best for relatively small, impervious watersheds.
- Filters in residential areas can present aesthetic and safety problems if constructed with vertical concrete walls.
- Certain designs maintain permanent sources of standing water where mosquito and midge breeding is likely to occur.

Performance

Sand filters are effective stormwater management practices for pollutant removal. With the exception of nitrates, which are always exported from filtering systems because of the conversion of ammonia and organic nitrogen to nitrate, they perform relatively well at removing pollutants, particularly sediment. Relative pollutant removal effectiveness of media filters is presented in Table 5-1.

Design Criteria and Procedure

T-11.1: Austin Sand Filter

There are two possible filter configurations used by Austin that may be considered.

- Full Sedimentation

  In this configuration, sedimentation occurs in a settling basin designed to hold the entire SQDV and release it to the filter over an extended draw-down time (40 hours). (See Figure 5-18 for typical configuration).

- Partial Sedimentation

  In this configuration, the settling basin holds a minimum of 20% of the water quality volume and does not incorporate an extended draw-down period. This basin removes the heavier sediment and large trash only and requires more intensive maintenance than the full sedimentation system. A larger filter surface area will be required to compensate for the more rapid clogging of the filter.

Design criteria for partial sedimentation are not included in this Plan due to the increased maintenance required for this type of control measure. This configuration will only be considered when it is adequately shown that space limitations will not allow full sedimentation, and other control measures recommended in this Plan are not viable alternatives.

Settling Basin Design

Settling basin design criteria for Austin Sand Filters with full sedimentation are summarized in Table 5-15.

Table 5-15. Austin Sand Filter Sedimentation Basin Design Criteria

Design Parameter	Unit	Design Criteria
Maximum drainage area	ac	100
Minimum basin depth	ft	3.0
Minimum surface area (A_s)	ft^2	SQDV ÷ 10 ft
Length to width ratio, L:W	–	2:1 or greater
Minimum draw-down time	hrs	40
Freeboard	ft	1.0 ft above maximum water surface elevation
Minimum basin volume	ft^3	SQDV + freeboard volume
Maximum inlet velocity	fps	3.0
Minimum particle sized removed	micron	20 (specific gravity = 2.65)

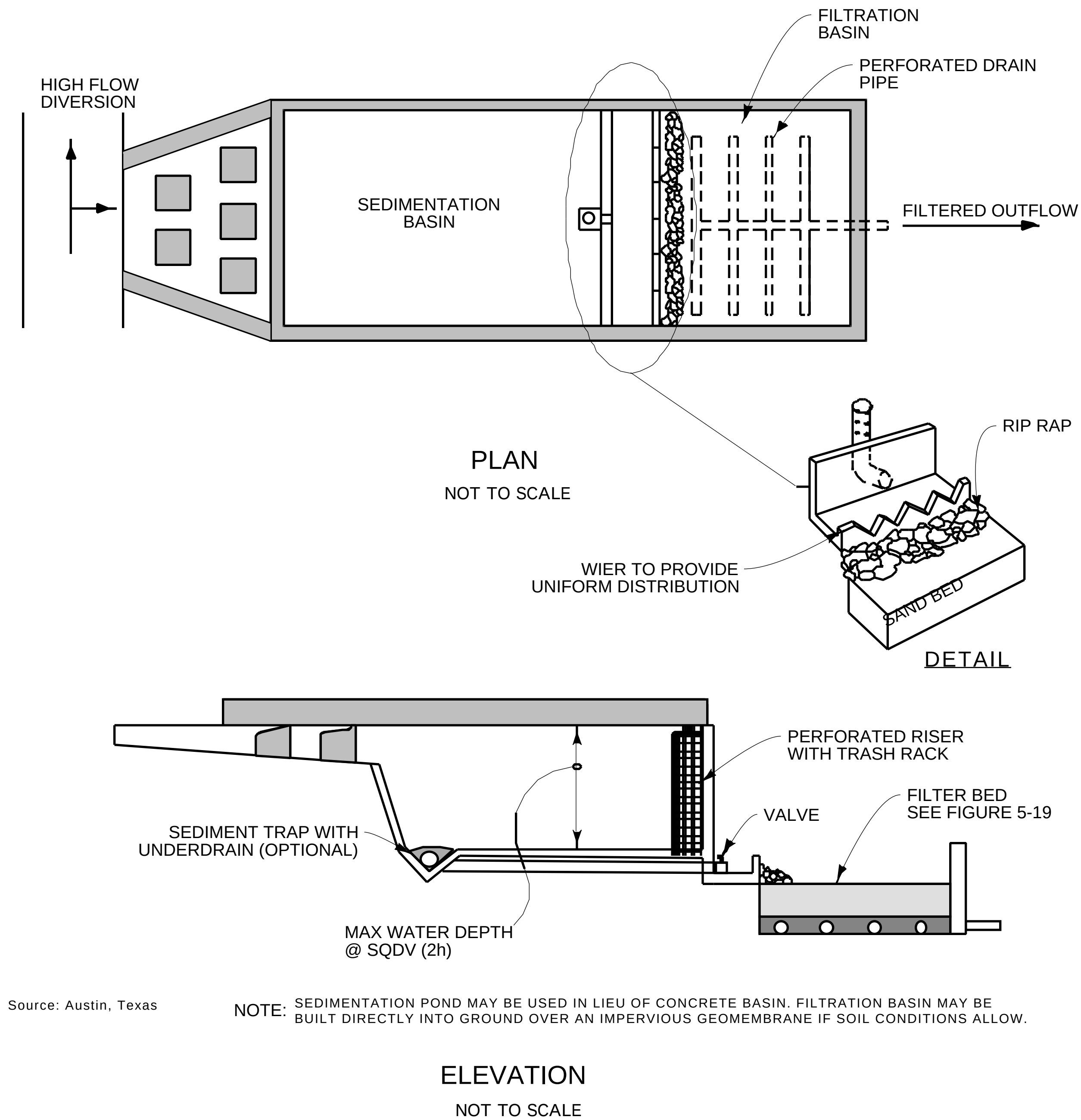


Figure 5-18. Austin Sand Filter

Design procedure and application of design criteria for Austin Filter Full Sedimentation Basin are outlined in the following steps:

1. Basin Storage Volume — Provide a storage volume equal to 100 percent of the SQDV, based on a 40-hr drawdown time, above the lowest outlet (i.e. perforation or orifice) in the basin.

   a. Determine the percent imperviousness of the tributary area (I_a).

   b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate.

   c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 40-hr drawdown and I_{wq} value from step 1.b.

   d. Calculate the SQDV in acre-ft as follows:

   $$SQDV = (V_u/12) \times Area$$

   where

   Area = Watershed area tributary to media filter (ac)

2. Inlet/Outlet Design — Basin inlet and outlet points should provided with an energy dissipation structure and/or erosion protection. Energy dissipation devices may be necessary in order to reduce inlet velocities that exceed three (3) feet per second.

3. Basin Shape — Whenever possible, shape the basin with a gradual expansion from the inlet and a gradual contraction toward the outlet. The sedimentation basin design should maximize the distance from where the heavier sediment is deposited near the inlet to where the outlet structure is located. This will improve basin performance and reduce maintenance requirements.

   Short circuiting (i.e., flow reaching the outlet structure before it passes through the sedimentation basin volume) flow should be avoided. Dead storage areas (areas within the basin which are by-passed by the flow regime and are, therefore, ineffective in the settling process) should be minimized. The length to width ratio should be a minimum of 2:1. Internal baffling may be necessary to achieve this ratio and could be used to mitigate short-circuiting and/or dead storage problems.

4. Trash Rack/Gravel Pack — A trash rack or gravel pack around perforated risers shall be provided to protect outlet orifices from clogging. Trash racks are better suited to use of perforated vertical plates for outlet control and allow easier access to outlet orifices for purposes of inspection and cleaning. Trash rack shall be sized to prevent clogging of the primary water quality outlet without restricting with the hydraulic capacity of the outlet controls orifices.

5. Sediment Trap (optional) — A sediment trap is a storage area that captures sediment and removes it from the basin flow regime. In so doing the sediment trap inhibits resuspension of solids during subsequent runoff events, improving long-term removal efficiency. The trap also maintains adequate volume to hold the water quality volume that would otherwise be partially lost due to sediment storage. Sediment traps may reduce maintenance requirements by reducing the frequency of sediment removal. It is recommended that the sediment trap volume be equal to 10 percent of the sedimentation basin volume. All water collected in the sediment trap shall drain out within 40 hours. The invert of the drain pipe should be above the surface of the sand bed filtration basin. The minimum grading of the piping to the filtration basin should be 1/4 inch per foot (two percent slope). Access for cleaning the sediment trap drain system is necessary.

6. Settling Basin Liner — If the sedimentation basin is an earthen structure and an impermeable liner is required to protect ground water quality, the liner shall meet the specifications for clay liner given in Table 5-20. The clay liner should have a minimum thickness of 12 inches. If an impermeable liner is not required then a geotextile fabric liner shall be installed that meets the specifications listed in Table 5-17 unless the basin has been excavated to bedrock. If a geotextile liner is used it should have a minimum thickness of 30 mils and be ultraviolet resistant.

<u>Filter Basin Design</u>

Filter basin design criteria for Austin Sand Filters are summarized in Table 5-16.

Table 5-16. Austin Sand Filter Basin Design Criteria

Design Parameter	Unit	Design Criteria
Minimum gravel depth over sand filter	in	2.0
Minimum water depth over filter, h	ft	3.0
Minimum sand depth, d_f	in	18.0
Minimum filtration rate of filter, k	ft/d	3.5
Slope of sand filter surface	%	0
Minimum gravel cover over underdrain	in	2
Sand size, diameter	in	0.02 – 0.04
Under drain gravel size, diameter	in	0.5 – 2.0
Minimum inside diameter underdrain	in	6.0
Underdrain pipe type	–	PVC schedule 40 (or thicker)
Minimum slope of underdrain	%	1.0
Minimum underdrain peroration, diameter	in	0.375
Minimum perorations per row	–	6
Minimum space between perforation rows	in	6
Maximum drawdown time, t_f	hrs	40.0
Minimum gravel bed depth, d_g	in	16

Design procedure and application of design criteria for Austin Sand Filter are outlined in the following steps:

1. Maximum Water Depth — Determine maximum allowable depth of water (2h) in the sedimentation basin considering elevation differences between inlet and outlet invert elevations of sedimentation basin and filter surface elevation. (This height will establish weir height or elevation of inlet invert for bypass pipes and orifices.)
2. Filter Surface Area — Surface area is the primary design parameter, and is a function of sand permeability, bed depth, hydraulic head and sediment loading. The required filter surface area (A_f) can be calculated using the following equation and design criteria provided in Table 5-16:

$$A_{fm} = \frac{(SQDV)(d_f)}{k(h + d_f)t_f}$$

where

WQV = SQDV, ft^3

A_{fm} = Filter surface area, ft^2

d_f	=	Sand bed depth, ft
k	=	Coefficient of permeability for sand filter (ft/hr)
h	=	One-half of maximum allowable water depth (2h) over filter, ft
t_f	=	Time required for runoff volume to pass through filter, hrs

3. Filter Basin Volume

The storage capacity of the filtration basin, above the surface of the filter media, should be greater than or equal to 20 percent of the SQDV. This capacity is necessary in order to account for backwater effects resulting from partially clogged filter media.

4. Inlet Structure

The inlet structure should spread the flow uniformly across the surface of the filter media. Flow spreaders, weirs or multiple orifice openings are recommended.

5. Filter Bed

The sand bed may be a choice of one of the two configurations given below. Note: Sand bed depths are final, consolidated depths. Consolidated effects must be taken into account.

1) Sand Bed with Gravel Layer (Figure 5-19A)

The sand layer is a minimum depth of 18 inches consisting of 0.02-0.04 inch diameter sand. Under the sand is a layer of 0.5 to 2.0-inch diameter gravel that provides a minimum of two inches of cover over the top of the underdrain lateral pipes. No gravel is required under the lateral pipes. A layer of geotextile fabric meeting the specifications in Table 5-17 must separate the sand and gravel and must be used to wrap around the lateral pipes.

Drainage matting meeting the specifications in Table 5-18 should be placed under the laterals to provide for adequate vertical and horizontal hydraulic conductivity to the laterals.

In areas with high sediment load (total suspended solids concentration ≥200 mg/L), the two-inch layer of stone on top of the sand filter should be underlain with Enkadrain 9120 filter fabric or equivalent meeting the specifications in Table 5-18.

2) Sand Bed - Trench Design (Figure 5-19B)

The top layer shall be 12-18 inches of 0.02-0.04 inch diameter sand. Laterals shall be placed in trenches with a covering of 0.5 to 2.0-inch gravel and geotextile fabric (see Table 5-17). The laterals shall be underlain by a layer of drainage matting (see Table 5-18).

In areas with high sediment load (total suspended solids concentration ≥200 mg/L), the two-inch layer of stone on top of the sand filter should be underlain with Enkadrain 9120 filter fabric or equivalent meeting the specifications in Table 5-19.

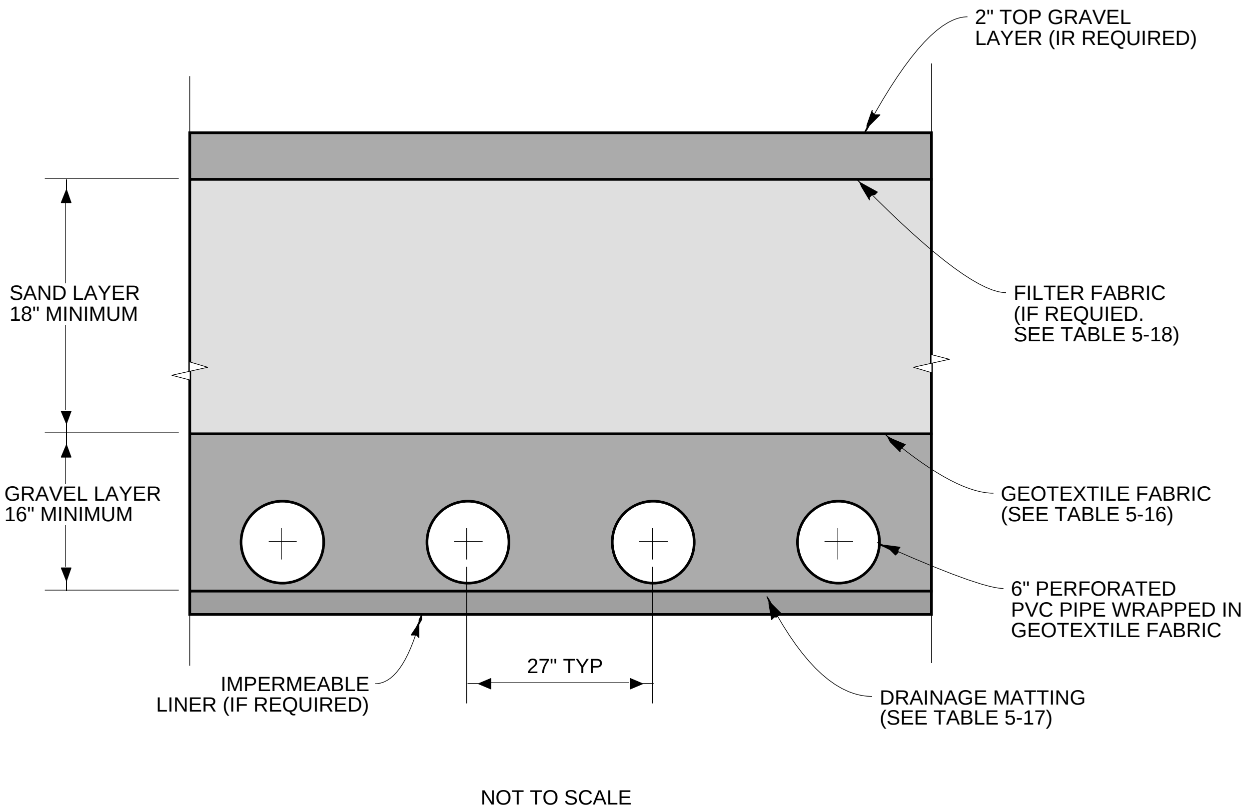


FIGURE 5-19A. FILTER BED WITH GRAVEL UNDERDRAIN

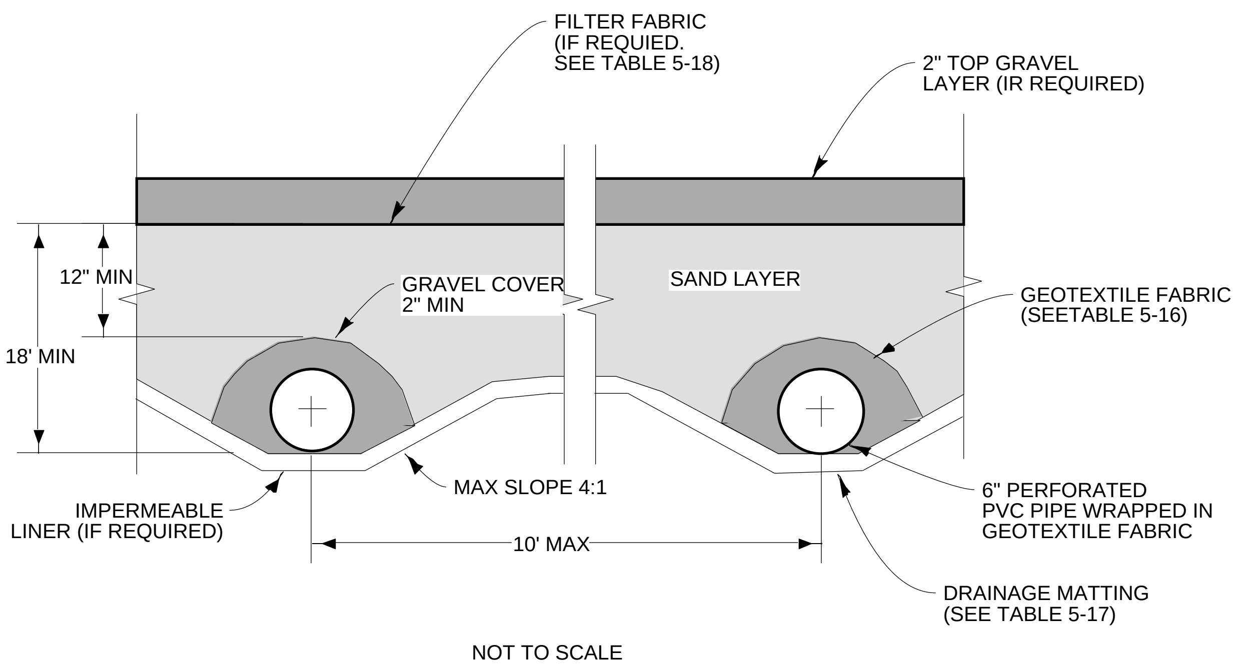


FIGURE 5-19B. FILTER BED WITH TRENCH UNDERDRAIN

Table 5-17. Geotextile Fabric Specifications

Property	Test Method	Unit	Specification
Material			Nonwoven geotextile fabric
Unit Weight		oz/yd^3	8 (min.)
Filtration Rate		in/sec	0.08 (min.)
Puncture Strength	ASTM D-751 (Modified)	lbs	125 (min.)
Mullen Burst Strength	ASTM D-751	psi	400 (min.)
Tensile Strength	ASTM-D-1682	lbs	300 (min.)
Equiv. Opening Size	US Standard Sieve	No.	80 (min.)

Table 5-18. Drainage Matting Specifications

Property	Test Method	Unit	Specification
Material			Nonwoven geotextile fabric
Unit Weight		oz/yd^3	20
Flow Rate (fabric)		gpm/ft^2	180 (min.)
Permeability	ASTM D-2434	cm/sec	12.4×10^{-2}
Grab strength (fabric)	ASTM D-1682	lbs	Dry Lg. 90 Dry Wd:70 Wet Lg.95 Wet Wd: 70
Puncture strength (fabric)	COE CW-02215	lbs	42 (min.)
Mullen burst strength	ASTM D-1117	psi	140 (min.)
Equiv. opening size	US Standard Sieve	No.	100 (70-120)
Flow rate (drainage core)	Drexel Univ. Test Method	gpm/ft width	14

Source: City of Austin

Table 5-19. Filter Fabric Specifications

Property	Test Method	Unit	Specification
Material			Non-woven geotextile fabric
Unit Weight		oz/yd^3	4.3 (min.)
Flow rate		gpm/ft^2	120 (min.)
Puncture Strength	ASTM D-751 (Modified)	lbs	60 (min.)
Thickness		in	0.8 (min.)

6. Underdrain Piping

The underdrain piping consists of the main collector pipe(s) and perforated lateral branch pipes. The piping should be reinforced to withstand the weight of the overburden. Internal diameters of lateral branch pipes should be six (6) inches or greater and perforations should be 3/8 inch. Each row of perforations should contain at least six (6) holes and the maximum spacing between rows of perforations should not exceed six (6) inches. All piping is to be schedule 40 polyvinyl chloride or greater strength. The minimum grade of piping shall be 1/8 inch per foot (one (1) percent slope)(slopes down to 0.5% are acceptable with prior approval). Access for cleaning all underdrain piping is needed.

Note: No draw-down time is to be associated with sand filtration basins, only with sedimentation basins. Thus, it is not necessary to have a specifically designed orifice for the filtration outlet structure.

7. Filter Basin Liner

If an impermeable liner is required to protect ground water quality it shall meet the specifications for clay liner given in Table 5-20. The clay liner should have a minimum thickness of 12 inches. If an impermeable liner is not required then a geotextile fabric liner shall be installed that meets the specifications listed in Table 5-17 unless the basin has been excavated to bedrock. If a geotextile liner is used it should have a minimum thickness of 30 mils and be ultraviolet resistant.

Table 5-20. Clay Liner Specifications

Property	Test Method	Unit	Specification
Permeability	ASTM D-2434	cm/sec	$1x10^{-6}$
Plasticity Index of Clay	ASTM D-423 & D-424	%	Not less than 15
Liquid Limit of Clay	ASTM D-2216	%	Not less than 30
Clay Particles Passing	ASTM D-422	%	Not less than 30
Clay Compaction	ASTM D-2216	%	95% of Standard Proctor Density

Source: City of Austin

<u>Design Example</u>

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-11.1: Austin Sand Filter (Page 1 of 2)

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	100	%
b. Effective Imperviousness (Determine using Figure 3-4)	I_{wq} =	100	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40-hr drawdown and I_{wq}	V_u=	0.60	in
d. Watershed Area Tributary to Media Filter	Area =	2.46	ac
e. Calculate SQDV SQDV = (V_u/12) × Area	SQDV =	0.123	ac-ft
2. Maximum Water Depth			
a. Storm drainage system invert elevation at proposed connection to storm drain	Inlet Elevation	90	ft
b. Minimum control measure outlet invert elevation of sand filter at minimum grade:	Outlet Elevation	90.75 @ 1%	ft
c, Estimate filter depth or use minimum depth of filter media and determine the difference in elevation between inverts of filter inlet and outlet:	Filter Depth	97.5	ft
d. Site plan surface elevation at control measure location	Surface Elevation	103.0	ft
e. Determine inlet invert elevation into sedimentation basin	Inlet Elevation (Sed. Basin)	100.0	ft
f. Determine maximum allowable depth of water (2h) in the sedimentation basin considering elevation differences between inlet and outlet invert elevations of sedimentation basin and filter and surface elevation. (This height will establish weir height or elevation of inlet invert for bypass pipes and orifices.)	Maximum Allowable Depth	3.0	ft

Design Procedure Form for T-11.1: Austin Sand Filter (Page 2 of 2)

Project:____

3. Filter Surface Area			
a. Sand Bed Depth	d_f =	1.5	ft
b. Coefficient of permeability for sand filter	k =	0.1458	ft/hr
c. One half of maximum allowable depth over filter (h).	h =	1.5	ft
d. Time required for runoff to pass through filter.	t_f =	40	hrs
e. Filter Surface Area (min.) $A_{fm} = \frac{(SQDV)(d_f)}{k(h+d_f)(t_f)}$	A_{fm} =	459	ft^2
4. Filter Basin Volume			
Filter Basin Volume = 0.2 _ SQDV	FBV =	1,072	ft^3

Notes:

T-11.2: DC Filter

The District of Columbia (D.C.) Environmental Regulation Administration developed an underground stormwater sand filter (referred to as the D.C. Sand Filter) contained in a structural shell with three chambers (see Figure 5-20). The shell may consist of precast or cast-in-place concrete.

The plunge pool in the first chamber and the throat of the second chamber, which are hydraulically connected by an underwater rectangular opening, absorbs energy and provides pretreatment, trapping grit and floating organic material such as oil, grease, and tree leaves. The second chamber contains a typical sand filter with a subsurface drainage system consisting of perforated PVC pipe in a stone bed. The third chamber, or clearwell, collects the flow from the underdrain pipes, and overflow pipes when installed, and directs the waters to the storm drainage system. A hooded large storm bypass pipe directly connecting the first chamber with the clearwell is illustrated in Figure 5-21. When storm flows are diverted upstream of the sediment chamber, an in-system overflow or bypass is neither necessary nor desired.

A major advantage of the D.C. sand filter is that it does not take up any space on the surface. It can be placed under on-site roadways (e.g., not public rights of way), parking lots, or sidewalks, and under planting spaces adjacent to buildings. The system works best for watersheds of approximately one acre of impervious surface. For larger watersheds, two or more DC sand filters will be required.

The load-carrying capacity of the filter structure must be considered when it is located under parking lots, driveways, roadways, and certain sidewalks (such as those adjacent to State highways). Traffic intensity may also be a factor. The structure must be designed by a licensed structural engineer. The effects of buoyancy must be considered in the design of an underground vault in areas with high ground water.

For cost, reliability, and maintenance considerations, it is preferable that the filter work by gravity flow. This requires sufficient vertical clearance between the invert of the prospective inflow storm piping and the invert of the storm drain which will receive the outflow.

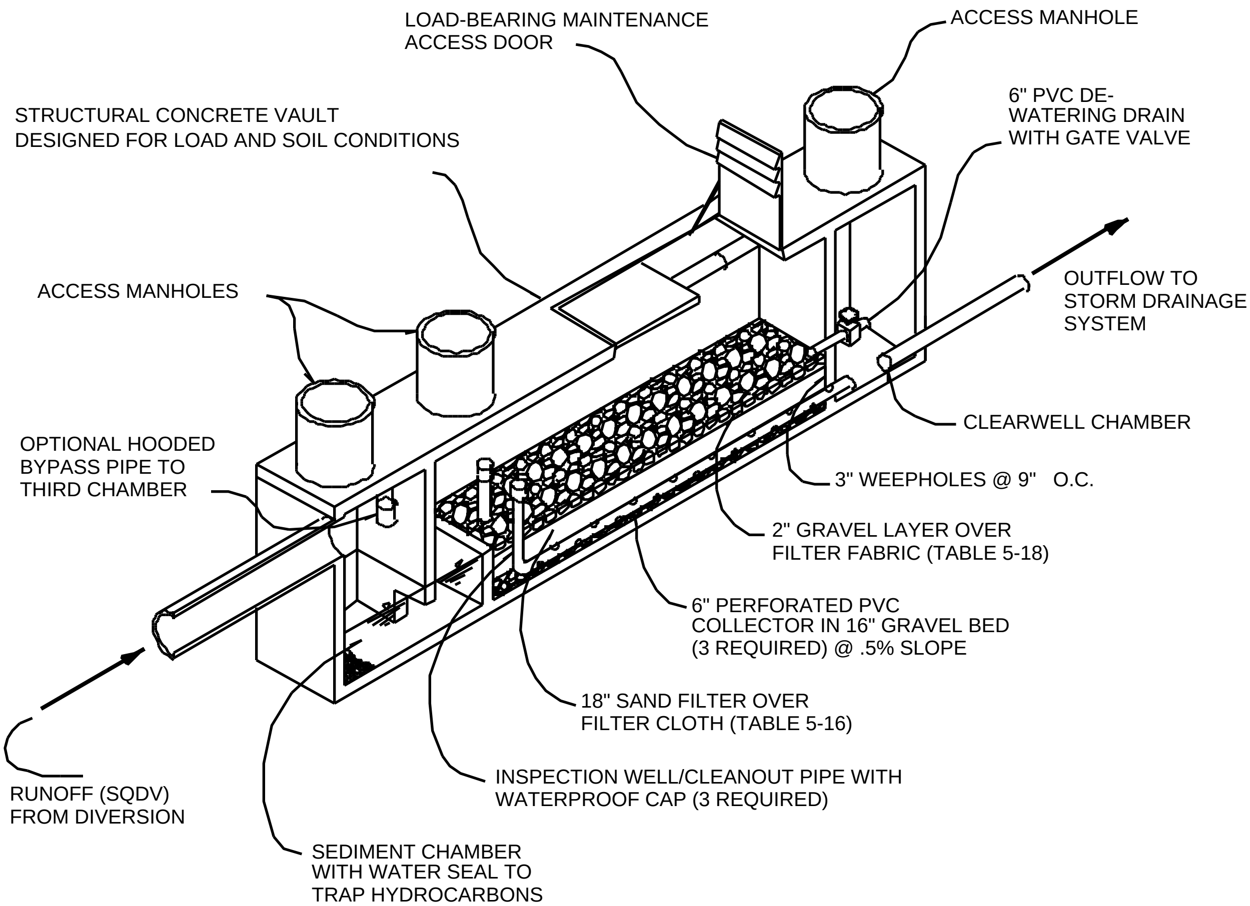
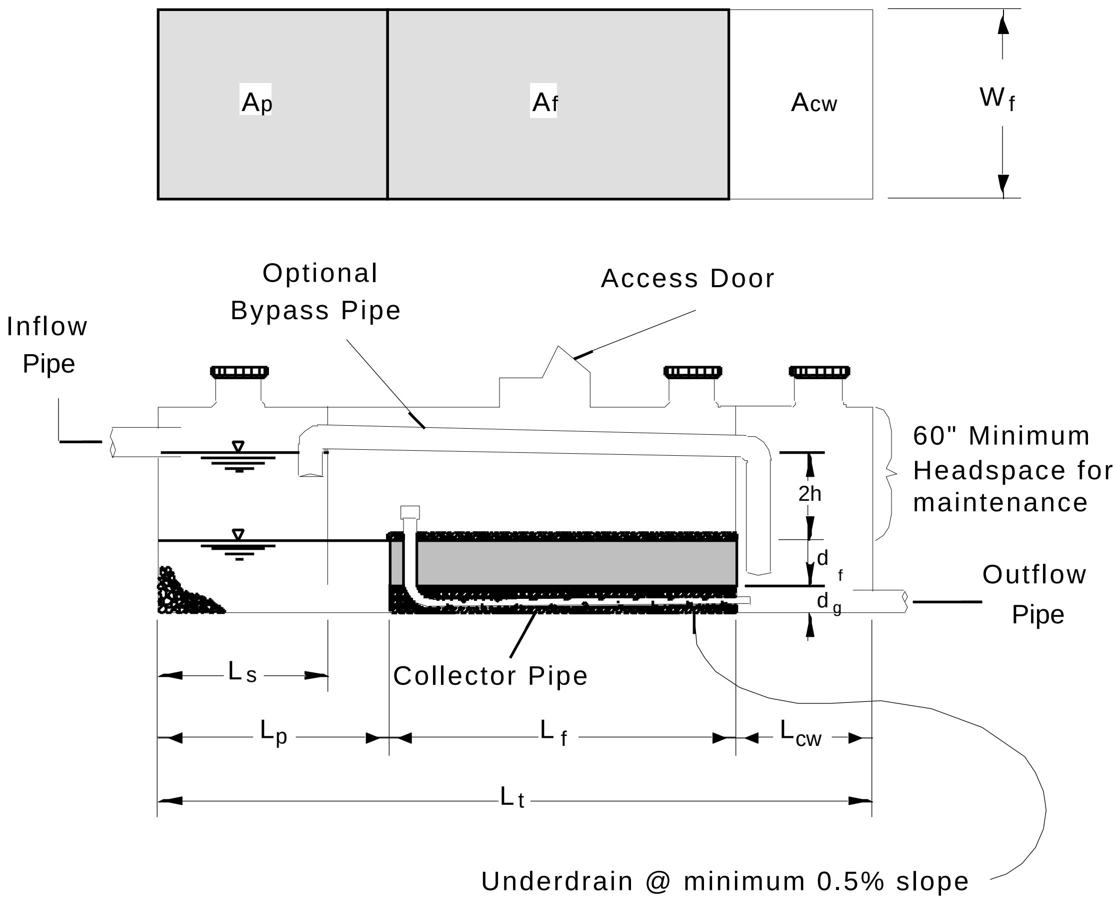


Figure 5-20. DC Sand Filter



Where:

A_p = Area of sediment chamber
A_f = Area of sand filter
A_{cw} = Area of clearwell
W_f = Width of filter
L_s = Minimum length of sediment chamber
L_p = Final length of permanent pool
L_f = Filter length
L_{cw} = Length of clearwell
L_t = Total length, sum of $L_p + L_f + L_{cw}$
2h = Maximum achievable ponding depth over filter
d_f = sand bed depth
d_g = gravel depth

Figure 5-21. Dimensional Relationships for DC Sand Filter

Design Criteria

Principal design criteria for DC Sand Filters are summarized in Table 5-21.

Table 5-21. DC Sand Filter Design Criteria

Design Parameter	Unit	Criteria Value
Maximum drainage area	ac	1.5
Maximum draw down time in filter, t_f	hrs	40
Minimum gravel depth over filter media	in	2.0
Minimum sand filter depth, d_f	in	18
Minimum gravel depth below filter, d_g	in	16
Minimum cover of gravel over underdrain pipe	in	2
Filter coefficient, k	ft/day	2
Minimum volume of SQDV to be contained in sediment chamber	%	20
Minimum slope of underdrain	%	1
Maximum diameter of upper level gravel cover	in	1
Minimum length of clearwell, L_{cw}	ft	3.0
Filter sand sizing	—	ASTM C 33 concrete sand
Minimum size diameter gravel in underdrain	in	0.5 to 2
Minimum size underdrain pipe	—	6-in Sch 40 reinforced PVC pipe
Minimum size diameter perforation in drainage pipe	in	3/8
Minimum number of perforation holes per underdrain pipe	—	6
Maximum spacing between perforation holes	in	6
Maximum spacing of underdrain pipes	in	27 (center to center)

Design Procedure

Design procedure and application of design criteria for DC Sand Filter are outlined in the following steps (see Figure 5-21 for dimensional relationships):

1. Maximum Water Depth — Determine maximum allowable depth of water (2h) in the filter basin considering elevation differences between inlet and outlet invert elevations. (This height will establish weir height or elevation of inlet invert for bypass pipes and orifices).

2. Sand Filter Area — Determine the minimum area of the DC Filter using the Austin Filter Formula for partial sedimentation treatment.

$$A_{fm} = \frac{(SQDV)(d_f)}{k(h + d_f)(t_f)}$$

where

A_{fm} = Filter surface area, ft^2

d_f = Sand bed depth, ft

k = Filter coefficient @ 0.0833 ft/hr

h = One-half of maximum allowable water depth (2h), ft

t_f = 40 hr draw-down time

3. Filter Width/Length

Considering site constraints, select a Filter Width (W_f). Then compute the Filter Length (L_f) using the minimum area required (A_{fm}).

$$L_f = A_{fm}/W_f$$

Round the length and determine adjusted area, A_f

$$A_f = W_f \times L_f$$

(After Note: From this point, formulas assume rectangular cross section of filter shell.)

4. Storage Volume

a. Above filter (V_{tf})

$$V_{tf} = A_f \times 2h$$

b. In filter voids (V_v), assuming 40% voids

$$V_v = A_f \times (d_f + d_g) \times (0.4)$$

5. Flow Through Filter During Filling (V_Q)

$$V_Q = k \times A_f \times (d_f + d_g) \times t_f/d_f$$

where

k = 2 ft/day = 0.0833 ft/hr

t_f = 1 hr to fill voids

6. Net Volume to be Stored in Sediment Chamber Awaiting Filtration (V_{st})

$$V_{st} = SQDV - V_{tf} - V_v - V_Q$$

7. Minimum Length of Permanent Pool (L_{pm})

$$L_{pm} = V_{st}/(2h)(W_f)$$

See Figure 5-21 for dimensional relationships.

8. Minimum Length of Sediment Chamber (L_s)

a. If $V_{st} > 0.2 \times (SQDV)$

$$L_s = V_{st}/(2h)(W_f)$$

b. If $V_{st} < 0.2 \times (SQDV)$

$$L_s = 0.2 \times (SQDV)/(2h)(W_f)$$

Note: It may be economical to adjust final dimensions to correspond with standard precast structures or to round off to simplify measurements during construction.

9. Final Length of Permanent Pool (L_p)

a. If $L_{pm} < (L_s + 2)$

$$L_p = L_{pm}$$

b. If $L_{pm} > (L_s + 2)$

$L_p = (L_s + 2)$

10. Length of Clearwell (L_{cw})

Set the length of the clearwell (L_{cw}) for adequate maintenance and/or access for monitoring flow rate and chemical composition of effluent (minimum 3 ft).

11. Filter Bed

a. Top Gravel Layer

The washed gravel layer at the top of the filter should be two inches thick composed of stone 0.5-inch to 2.0-inch diameter in size.

In areas with high sediment load (TSS concentration >200 mg/L), the two-inch layer of stone on top of the sand filter should be underlain with filter fabric meeting the specifications in Table 5-20.

b. Sand Layer

The sand layer should be a minimum depth of 18 inches consisting of ASTM C33 concrete sand. A layer of geotextile fabric meeting the specifications in Table 5-17 must separate the sand and gravel layer below.

c. Gravel Layer

The gravel layer surrounding the collector pipes should be at least 16 inches thick and be composed of 0.5 to 2-inch diameter stone and provide at least two inches of cover over the tops of the drainage pipes.

12. Underdrain Piping

The underdrain piping consists of the main collector pipe(s) and perforated lateral branch pipes. The piping should be reinforced to withstand the weight of the overburden. Internal diameters of lateral branch pipes should be six (6) inches or greater and perforations should be 3/8 inch. Each row of perforations should contain at least six (6) holes and the maximum spacing between rows of perforations should not exceed six (6) inches. All piping is to be schedule 40 polyvinyl chloride or greater strength. The minimum grade of piping shall be 1/8 inch per foot (one (1) percent slope)(Note: slopes down to 0.5% are acceptable with prior approval). Access for cleaning all underdrain piping is needed.

13. Weep Holes

In addition to the underdrain pipes, weepholes should be installed between the filter chamber and the clearwell to provide relief in case of pipe clogging. The weepholes should be three (3) inches in diameter. Minimum spacing should be nine (9) inches center to center. The openings on the filter side of the dividing wall should be covered to the width of the trench with 12 inch high plastic

	hardware cloth of 1/4 inch mesh or galvanized steel wire, minimum wire diameter 0.03-inch, number 4 mesh hardware cloth anchored firmly to the dividing wall structure and folded a minimum of six (6) inches back under the bottom stone.
14. Dewatering Drain	A six (6) inch diameter DIP or PVC dewatering drain with a gate valve is to be installed at the top of the stone/sand filter bed through the partition separating the filtration chamber from the clearwell chamber.
15. Bypass Pipe	Where a bypass pipe is needed, it shall be DIP or PVC with supports every 18 inches minimum.

Design Example

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-11.2:: DC Sand Filter (Page 1 of 2)

Designer: ______________________________

Company: ______________________________

Date: ______________________________

Project: ______________________________

Location: ______________________________

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	100	%
b. Effective Imperviousness (Determine using Figure 3-4)	I_{wq} =	100	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40-hr drawdown and I_{wq}	V_u=	0.60	in
d. Watershed Area Tributary to Media Filter	Area =	1.0	ac
e. Calculate SQDV SQDV = (V_u/12) × Area	SQDV =	0.050	ac-ft
2. Minimum Filter Area $A_{fm} = \frac{(SQDV)(d_f)}{k(h + d_f)(t_r)}$			
a. SQDV	SQDV =	2,178	ft^3
b. Sand bed depth (d_f)	d_f =	1.5	ft
c. Filter Coefficient (k)	k =	0.0833	ft/hr
d. Draw-down time (t_r = 40 hrs)	t =	40	hr
e. one half maximum allowable water depth over filter (h)	h =	1.67	ft
f. Minimum filter area	A_{fm} =	309.3	ft^2
3. Select Filter Width, Compute Filter Length			
a. Select a Filter Width (W_f)	W_f =	12.0	ft
b. Compute filter length $L_f = A_{fm}/W_f$	L_f =	40.1	ft
c. Determine adjusted filter area (Round L_f to closest whole number) A_f = $W_f \times L_f$	A_f =	312	ft^2
(From this point, the formula assumes rectangular cross section of filter shell.)			

Design Procedure Form for T-11.2: DC Filter (Page 2 of 2)

Project:____________________

4. Compute the Storage Volume of Top of the Filter (V_{tf}) $V_{tf} = A_f \times 2h$	V_{tf} = 11,042 ft^3
5. Compute the Storage in the Filter Voids (Vv) (Assume 40% voids in the filter media) $V_v = A_f \times (d_f + d_g) \times 0.40$	V_v = 353.6 ft^3
6. Flow Through Filter During Filling (V_Q) (Assume 1-hr to fill) $V_Q = k \times A_f \times (d_f + d_g) \times t_f / d_f$ Use: k = 2 ft/day = 0.0833 ft/hr. t_f = 1 hr. to fill voids	V_Q = 54.5 ft^3
7. Compute Net Volume to be Stored in Permanent Pool Awaiting Filtration (V_{st}) $V_{st} = SQDV - V_{tf} - V_v - V_Q$	V_{st} = 727.9 ft^3
8. Compute Minimum Length of Permanent Pool (L_{pm}) $L_{pm} = V_{st} /(2h) \times (W_f)$	L_{pm} = 18.16 ft
9. Compute Minimum Length of Sediment Chamber (L_s) (to contain 20% of SQDV) If $V_{st} < (0.2 \times SQDV)$, use: $L_s = 0.2SQDV /(2h)\_(W_f)$ If $V_{st} > (0.2 \times SQDV)$, use: $L_s = V_{st} /(2h) \times (W_f)$	L_s = 18.16 ft
10. Set Final Length of Permanent Pool (L_p) If $L_{pm} \geq (L_s + 2\text{ ft})$, use: $L_p = L_m$ If $L_{pm} < (L_s + 2\text{ ft})$, use: $L_p = (L_s + 2\text{ ft})$	L_p = 20.16 ft
11. Set Final Length of Clear Well (L_{cw}) L_{cw} = 3 ft (min.)	L_{cw} = 4.0 ft

Notes: ____________________

T-11.3: Delaware (Linear) Sand Filter

A schematic drawing of the modified Delaware Sand Filter (DSF) is shown in Figure 5-22. The system consists of two parallel concrete trenches divided by a close-spaced wall. The first trench serves as the sedimentation chamber. When accepting sheet flow, it is fitted with a grated cover. Concentrated stormwater may also be conveyed to the chamber in enclosed storm drain pipes. The second chamber, which contains the sand filter, is always fitted with a solid cover.

Storm flows enter the sedimentation chamber through the grates, causing the sedimentation pool to rise and overflow into the filter chamber through the weir notches at the top of the dividing wall. This provides assurance that the water to be treated arrives at the filter as sheet flow. This is essential to prevent scouring of the sand. The permanent pool in the sedimentation chamber is dead storage, which inhibits resuspension of particles that were deposited in earlier storms and prevents the heavier sediments from being washed into the filter chamber. Floatable materials and hydrocarbon films, however, may reach the filter media through the surface outflow.

The second trench contains the top 2 inches stone filter layer, the middle 18 inches of sand, and the bottom 16-inch stone layer. Six-inch diameter PVC underdrains are provided in this stone layer to carry the filtered water to the clearwell and ultimately to the storm drain. For smaller units, less than 20 feet in length, a gravel underdrain bed with the weep holes may be used in place of PVC pipe.

For systems where storm flows in excess of the SQDV are not diverted upstream of the filter, an overflow weir into the clearwell from the sedimentation chamber will convey the runoff greater than the SQDV directly to the storm sewer. The overflow weir shall be sized to pass volume of water that exceeds the SQDV. Where retention of hydrocarbons is a concern, the weir should be fitted with a metal hood or commercial catch basin trap.

To ensure the filter can be drained if plugged, a 6-inch dewatering drain with gate valve is included in the design of the filter.

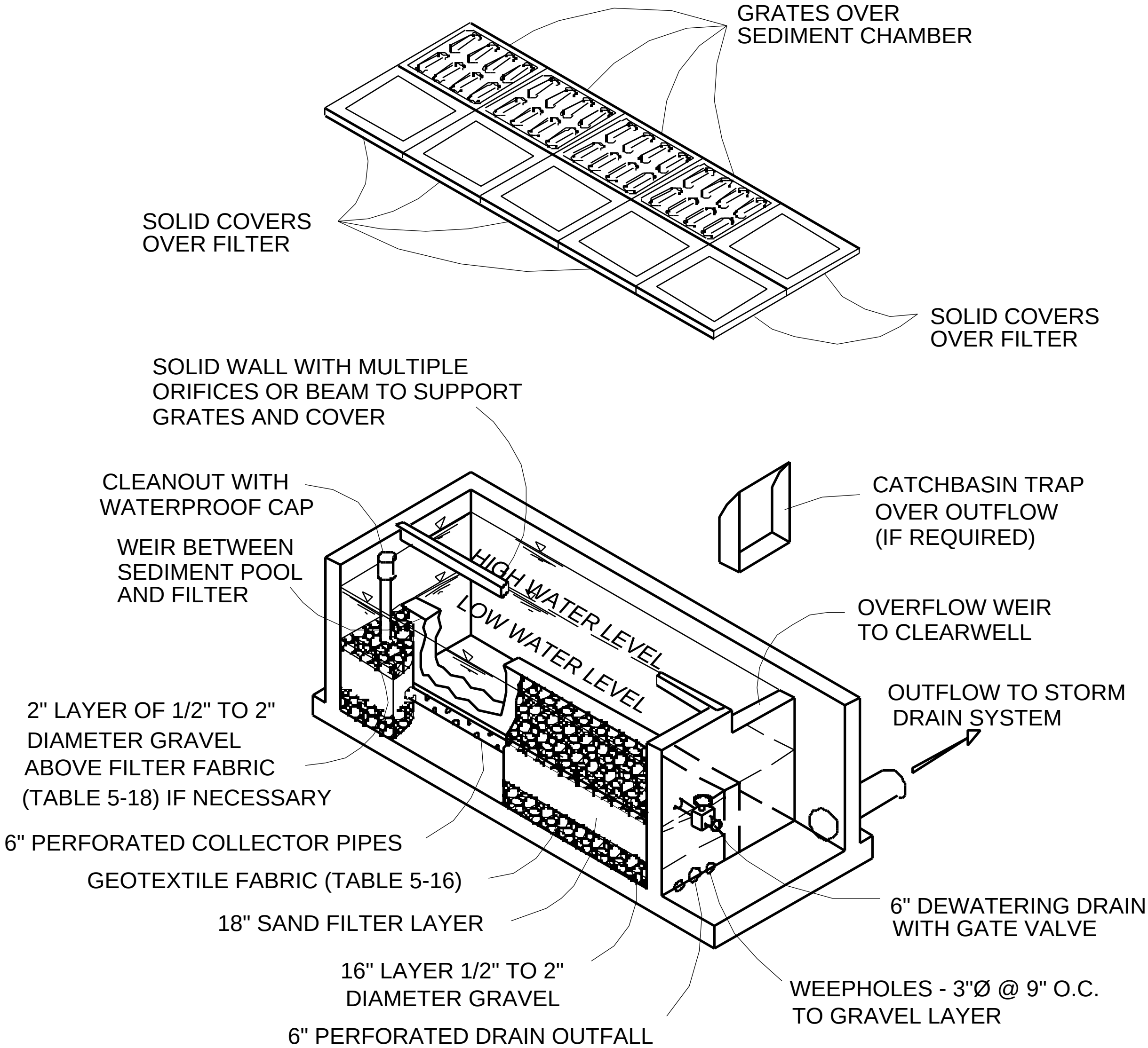


Figure 5-22. Delaware Sand Filter

Design Criteria

Principal design criteria for the Delaware Sand Filter are summarized in Table 5-22

Table 5-22. Delaware Sand Filter Design Criteria

Design Parameter	Unit	Criteria
Maximum drainage area	ac	5
SQDV	ac-ft	80% annual capture. Use Figure 5-1 @ 40-hr drawdown
Weir height between sedimentation chamber and sand filter	in	Set weir height 2” above sand filter bed
Minimum draw down time, t_f	hrs	40
Minimum gravel depth over sand	in	2
Minimum sand depth, d_f	in	18
Minimum gravel underdrain depth, d_g	in	16
Filter coefficient, k	ft/day	2.0
Top layer and underdrain gravel size	in	0.5 to 2-in diameter stone
Sand size	—	ASTM C33 concrete sand
Slope of top layer	%	0 (horizontal)
Minimum slope of underdrain or bottom of filter	%	0.5%
Minimum size underdrain	—	6-in PVC schedule 40
Minimum size diameter perforation	in	3/8
Minimum number of holes per row	—	6
Minimum spacing between rows	in	6
Minimum weephole diameter	in	3
Minimum spacing between weepholes	in	9 (center to center)
Sedimentation chamber and sand filter width	in	18 to 30

Design Procedure

Design procedure and application of design criteria for Delaware Sand Filter are outlined in the following steps:

1. Maximum Water Depth — Based on site constraints determine the maximum ponding depth over filter (2h). If an overflow device is built into the DSF shell, size the overflow weir in procedures in Appendix B.

2. Sand Filter/Sediment Chamber Surface Area — The DSF shell must have the capacity to accept and store the SQDV. The dimensions are sized to provide a filter area which processes the SQDV in the desired time frame (40 hrs.). The areas of the sedimentation chamber and filter bed are typically set equal. The required areas are calculated as follows depending on the maximum depth of water above the filter bed:

   a. If $2h < 2.67$ ft

$$A_{sm} = A_{fm} = SQDV/(4.1h + 0.9)$$

b. If 2h > 2.67 ft

$$A_{sm} = A_{fm} = \frac{(SQDV)(d_f)}{(k)(h + d_f)(t_f)}$$

where

SQDV = Stormwater Quality Design Volume, ft^3

A_{fm} = Filter surface area, ft^2

A_{sm} = Sediment chamber area, ft^2

d_f = sand bed depth, ft

k = Filter coefficient @ 0.0833 ft/hr

h = One-half of max allowable water depth (2h), ft

t_f = 40 hr drawdown time

3. Select sediment chamber and filter width ($W_s = W_f$)

Site considerations usually dictate the final dimensions of the facility. Sediment chambers and filter chambers are normally 18-30 inches wide. Use of standard grates requires a width of 26 inches.

4. Sediment Chamber/ Filter Length

$$L_s = L_f = A_{fm}/W_f$$

Round length upward as appropriate. Compute adjusted area

$$A_s = A_f = W_f \times L_f$$

5. Storage Volume in filter voids (V_v)

$$V_v = A_f \times (d_f + d_g) \times (0.4) \quad \{\text{assuming 40\% voids}\}$$

6. Flow Through Filter During Filling (V_Q)

$$V_Q = k \times A_f \times (d_f + d_g) \times t_f/d_f$$

where

k = 2 ft/day = 0.0833 ft/hr

t_f = 1 hr to fill voids

7. Net Volume Required to be Stored in Chambers Awaiting Filtration (V_{st})

$$V_{st} = SQDV - V_v - V_Q$$

8. Available Storage in Chambers (V_{sf})

$$V_{sf} = 2h \times (A_f + A_s)$$

If $V_{sf} \geq V_{st}$, proceed with design.

If $V_{sf} < V_{st}$, adjust width and/or length and repeat steps 3-8.

9. Filter Bed

a. Top Gravel Layer

a. Top Gravel Layer

The washed gravel layer at the top of the filter should be two inches thick composed of stone 0.5 to 2.0 inches in diameter.

In areas with high sediment load (TSS concentration >200 mg/L), the two-inch layer of stone on top of the sand filter should be underlain with filter fabric meeting the specifications in Table 5-19.

b. Sand Layer

The sand layer should be a minimum depth of 18 inches consisting of ASTM C33 concrete sand. A layer of geotextile fabric meeting the specifications in Table 5-17 must separate the sand and gravel layer below.

c. Gravel Layer

The gravel layer surrounding the collector pipes should be at least 16 inches thick and be composed of 0.5 to 2-inch diameter stone and provide at least two inches of cover over the tops of the drainage pipes.

10. Underdrain Piping — The underdrain piping should follow the same criteria and design as the Austin Sand Filter (see T-11.1).

Shallow rectangular drain tiles may be fabricated from such materials as fiberglass structural channels, saving several inches of filter depth. Drain tiles should be in two-foot lengths and spaced to provide gaps 1/8-inch less than the smallest gravel sizes on all four sides. Sections of tile may be cast in the dividing wall between the filter and the clearwell to provide shallow outflow orifices.

11. Weepholes — Weephole configuration should follow the same criteria as the DC Sand Filter (see T-11.2).

12. Grates and Covers — Grates and cast steel covers are designed to take the same wheel loads as the adjacent pavement. Where possible, use standard grates to reduce costs. Grates and covers should be supported by a galvanized steel perimeter frame.

13. Hoods/Traps — In applications where trapping of hydrocarbons and other floating pollutants is required, large-storm overflow weirs should be equipped with a 10-gauge aluminum hood or commercially available catch basin trap. The hood or trap should extend a minimum of one foot into the permanent pool.

14. Dewatering Drain — A six inch diameter dewatering drain with gate valve is to be installed at the top of the stone/sand filter bed through the partition separating the filter chamber from the clearwell chamber.

<u>Design Example</u>

Design forms to document the design procedure are provided in Appendix G. A completed design form follows as a design example.

Design Procedure Form for T-11.3: Delaware Sand Filter

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Minimum Surface Areas of the Chambers			
If 2h < 2.67 ft (2'-8")			
$A_{sm} = A_{fm} = SQDV/(4.1\_h + 0.9)$			
If 2h > 2.67 ft (2'-8")			
$A_{sm} = A_{fm} = \frac{(SQDV)(d_f)}{k\,t_f\,(h + d_f)}$			
a. SQDV	SQDV =	1300	ft^3
b. Sand bed depth (d_f)	d_f =	1.5	ft
c. Filter Coefficient (k)	k =	0.0833	ft/hr
d. Draw-down time (t_r)	t =	40	hr
e. One half maximum allowable water depth over filter (h)	h =	1.67	ft
f. A_{sm} (Sediment Chamber Area) and A_{fm} (Filter Surface Area)	A_{sm} and A_{fm} =	185	ft^2
2. Sediment Chamber and Filter Width/Length			
a. Select width ($W_s = W_f$ = 18-30 in)	$W_s = W_f$ =	2.167	ft
b. Filter length ($L_s = L_f = A_{fm}/W_f$)	$L_s = L_f$ =	85.2	ft
c. Adjusted length (rounded)	$L_s = L_f$ =	86.0	ft
d. Adjusted area ($A_s = A_f = W_f \times L_f$)	$A_s = A_f$ =	186.4	ft^2
3. System Storage Volume			
a. Storage in filter voids ($V_v = A_f \times (d_f + d_f) \times 0.4$)	V_v =	211.0	ft
b. Flow through filter ($V_Q = k \times A_f \times (d_f + h)$ 1hr/d_f)	V_Q =	32.8	ft
c. Required net storage ($V_{st} = SQDV - V_v - V_Q$)	V_{st} =	1,056	ft
d. Available storage ($V_{sf} = 2h \times (A_f + A_s)$)	V_{sf} =	1,245	ft^2
If $V_{sf} \geq V_{st}$, sizing is complete			
If $V_{sf} < V_{st}$, repeat steps 2 and 3			

Construction Considerations

- Erosion and sediment control measures must be configured to prevent any inflow of stormwater into the sand filter during its construction.
- The sand filter must be adequately protected once constructed and not be placed in service until all soil surfaces in the drainage watershed have been stabilized with vegetated cover. Should construction runoff enter the filter system prior to site revegetation, all contaminated materials must be removed and replaced with new clean materials.
- The top of the sand filter must be completely level. No grade is allowed.
- The inverts of the notches, multiple orifices, or weirs dividing the sedimentation chamber from the filter chamber must also be completely level. Otherwise, water will not arrive at the filter as sheet flow and only the downgradient end of the filter will function.
- Inflow grates or slotted curbs may conform to the grade of the completed pavement as long as the filters, notches, multiple orifices, and weirs connecting the sedimentation and filter chambers are completely level.
- If precast concrete lids are used, lifting rings or threaded sockets must be provided to allow easy removal with lifting equipment. Lifting equipment must be readily available to the facility operators.
- Where under-drains are used, the minimum slope of the pipe shall be 0.5%. Where only gravel filtered water conveyance is provided, the filter floor must be sloped towards the weepholes at a minimum slope of 0.5%.

Maintenance Requirements

Maintenance Agreement

On-site treatment control measures are to be maintained by the owner/operator. Maintenance agreements between the City and the owner/operator may be required. A Maintenance Agreement with the City must be executed by the owner/operator before the improvement plans are approved.

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the City's request. The Maintenance Plan should address items such as:

- Operation plan and schedule, including a site map;
- Maintenance and cleaning activities and schedule;
- Equipment and resource requirements necessary to operate and maintain facility; and
- Responsible party for operation and maintenance.

Additional guidelines for Maintenance Plans are provided in Appendix D.

Maintenance Activities

The following activities are recommended to properly maintain media filters:

- During the first year of operation, the cover grates or precast lids on the chambers must be removed quarterly and an inspection made to assure that the system is functioning. Once the system is functioning properly, this inspection may be made on a semiannual basis.
- Grass must be prevented from washing into the filter.
- Disposal of petroleum hydrocarbon contaminated sand, gravel, or filter cloth must be done in accordance with all applicable laws.
- Trash collected on the grates protecting the inlets should be removed no less frequently than weekly to assure preserving the inflow capacity of the control measure.
- Inspections semiannually for standing water, sediment, trash and debris, and to identify and correct potential problems.
- Inspect the facility once during the wet season after a large rain event to determine whether the facility is draining completely within 72 hours.
- Remove top two inches of sand and dispose of sediment if facility drain time exceeds 72 hours. Discoloration of the filter may be an indication of clogging. Restore media depth to 18 inches when overall media depth drops to 12 inches.
- Remove accumulated sediment in the sedimentation basin every ten years or when the sediment occupies ten percent of the basin volume, whichever is less.

Monitoring Agreement

The owner/operator may be required to enter into a monitoring agreement with the City to establish pollutant removal efficiencies of the sand filter.

Sand filters may be required to be designed to accommodate the installation, operation and maintenance of automatic sampling equipment to measure the input and output flow rates and the chemical composition of the inflow and outflow.

At a minimum, the sand filter system will be equipped with monitoring manholes in the inflow and outflow pipes. The City and its consultants will conduct the monitoring program unless otherwise agreed to by the agency. The type and length of monitoring program will be determined on a case-by-case basis.

Retention/Irrigation

Description

Retention/Irrigation is the capture of stormwater runoff in a holding pond and its subsequent use for irrigation of landscape or natural pervious areas. This technology is very effective as a stormwater treatment practice because it provides nearly zero discharge to receiving waters and high stormwater pollutant removal efficiencies. This technology mimics natural undeveloped watershed conditions where the vast majority of rainfall volume during smaller rainfall events is infiltrated through the soil profile. A conceptual layout of a Retention/Irrigation system is shown in Figure 5-23.

This technology has been applied to a limited extent for stormwater treatment. The guidelines presented below should be considered tentative until additional data are available.

General Application

This practice is particularly appropriate for areas with infrequent rainfall and can be used in any type of soil. Capture of stormwater can be accomplished by almost any kind of runoff storage facility, ranging from dry, concrete-lined ponds to those with vegetated basins and permanent pools. Generally, a spray irrigation system is required to provide an adequate flow rate for distributing the water quality volume. Collection of roof runoff for subsequent use (rainwater harvesting) also qualifies as a retention/irrigation practice.

Advantages

- Retention/Irrigation spreads runoff over a large area for evaporation and infiltration.
- Pollutant removal effectiveness is generally high for most pollutants and is accomplished primarily by sedimentation in the primary storage facility, physical filtration through the soil profile, and uptake and adsorption in the vegetative root zone by the soil-resident microbial community and by soil and organic particles.
- The hydrologic characteristics of this technique are effective for simulating pre-developed watershed conditions through containment of higher frequency flood volumes and reduction of flow rates and velocities for erosive events.
- The use of stormwater for irrigation can reduce demand on surface and groundwater supplies.

Disadvantages

- Retention/Irrigation is a relatively expensive technology due primarily to mechanical systems, power requirements, and high maintenance needs.
- The complexity of the irrigation system requires regular inspection and maintenance.
- Retention/Irrigation systems use pumps requiring electrical energy inputs.
- Retention/Irrigation systems require open space for irrigation and may be difficult to use in urban areas.

- Effective use of Retention/Irrigation requires some form of pre-treatment of runoff flows (i.e. sediment forebay or vegetated filter) to remove coarse sediment and to protect the long-term operating capacity of the irrigation equipment.
- Retention/irrigation captures and stores water that can provide breeding habitat for mosquitoes and other vectors.

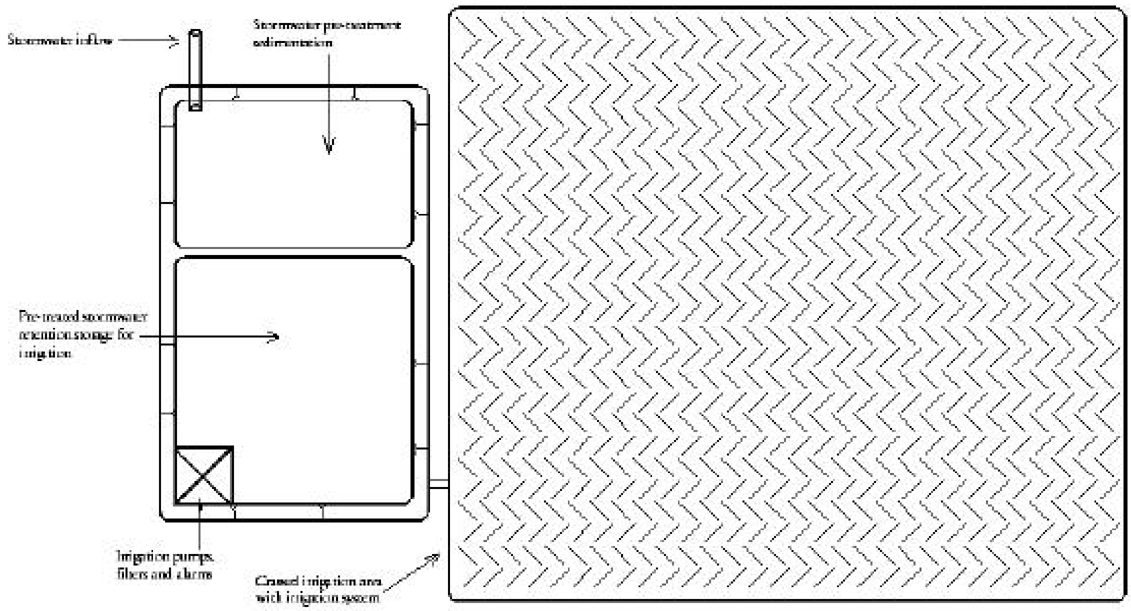


Figure 5-23 Retention/Irrigation

Performance

There are no published reports on its effectiveness, cost, or operational requirements, due to the limited experience with this technology for stormwater treatment.

Design Criteria and Procedure

Principal design criteria for retention/irrigation systems are listed in Table 5-22.

Table 5-23. Retention/Irrigation System Design Criteria

Design Parameter	Unit	Design Criteria
SQDV Design Drawdown Time	hrs	40
Irrigation period for SQDV	hrs	60
Irrigation area maximum slope	%	10
Soil cover	in	12
Soil type	–	Soil particles > 0.5” should not account for more than 30% of the soil volume
Soil permeability	in/hr	0.1 unless actual site data is available

Design Parameter	Unit	Design Criteria
Buffer Distance from wells, septic systems, and natural wetlands	ft	100

Design procedure and application of design criteria are outlined in the following steps:

1. Storage Basin Volume — Provide a storage volume equal to 100 percent of the SQDV, based on a 40-hr drawdown time, above the lowest outlet (i.e. perforation or orifice) in the basin.

   a. Determine the percent imperviousness of the tributary area (I_a).

   b. Determine effective imperviousness (I_{wq}) by adjusting for site design source controls using Figure 3-4, as appropriate.

   c. Determine required unit basin storage volume (V_u) using Figure 5-1 with 40-hr drawdown and I_{wq} value from step 1.b.

   d. Calculate the SQDV in acre-ft as follows:

   $$SQDV = (V_u/12) \times Area$$

   where

   Area = Watershed area tributary to media filter (ac)

2. Irrigation Area — Determine the irrigation area such that no surface runoff is produced.

   $$A = (12 \times SQDV)/(T \times r)$$

   where

   A = Area required for irrigation (ft^2)

   SQDV = Stormwater quality design volume (ft^3)

   T = Period of active irrigation (60 hrs)

   r = Permeability (in/hr)

3. Detention Time — The irrigation schedule should allow for complete discharge of the SQDV within 72 hours. Irrigation should not begin within 12 hours of the end of rainfall so that direct storm runoff has ceased and soils are not saturated. Consequently, the length of the active irrigation is 60 hours and should include a cycling factor of 1/2 so that each portion of the area will only be irrigated for 30 hours. Irrigation should not occur during subsequent rainfall events

4. Maximum Slope — The maximum slope of the irrigation area should be less than 10%.

5. Soil Cover — A minimum of 12 inches of soil cover is required for the

		irrigation area.
6.	Soil Type	Rocky soils are acceptable for irrigation, but coarse material (diameter greater than 0.5 inches) should not account for more than 30% of the soil volume.
7.	Soil Permeability	The permeability of the soils in the proposed irrigation area should be measured using long-term infiltration tests or obtained from Soil Surveys from the Resource Conservation Service. If there is a range of permeabilities, the average value should be used. If there are no permeability data available, the assumed permeability should be 0.1 inches/hour.
8.	Buffer Distance	The irrigation area should be distinct and different from any area used for wastewater effluent irrigation. The irrigation area should also be at least 100 feet away from wells, septic tanks, and natural wetlands.
9.	Pump and Wet Well	A reliable pump, wet well, and rainfall or soil moisture sensor system should be used to distribute the SQDV. These systems are similar to those used for wastewater effluent irrigation.

Design Example

A completed design form follows as a design example. Blank design forms are provided in Appendix G.

Design Procedure Form for T-12: Retention/Irrigation

Designer: ______________________

Company: ______________________

Date: ______________________

Project: ______________________

Location: ______________________

1. Determine Basin Storage Volume	
a. Percent Imperviousness of Tributary Area	I_a = 70 %
b. Effective Imperviousness (Determine using Figure 3-4)	I_{wq} = 66 %
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40-hr drawdown and I_{wq}	V_u = 0.44 in
d. Watershed Area Tributary to Infiltration Trench	Area = 20 ac
e. Calculate SQDV SQDV = (V_u/12) × Area	SQDV = 0.73 ac-ft SQDV = 31,800 ft^3
2. Irrigation Area	
Infiltration rate (r)	r = 0.10 in/hr
A = (SQDV × 12)/(60 × r)	A = 63,600 ft^2
3. Vegetation (describe)	Tall Fescue

Notes:

Construction Considerations

Scheduling

Vegetation in the irrigated area should be established and operational by October 1, unless another schedule has been justified in the Landscape Plan and approved by the City. To meet the October 1 deadline, the following schedule must be met:

- Seeding should be conducted during the dry season, no later than September 1 to ensure sufficient vegetation by October 1. Irrigation may be required.
- Within 60 days of seeding, or by September 30, whichever is earlier, the site shall be inspected to determine adequacy of vegetation growth, and to determine if erosion or damage has occurred. Areas of damage shall be repaired, seeded, and mulched immediately.
- If vegetation growth is insufficient, or excessive damage or erosion has occurred, the site will be further stabilized with other appropriate erosion control measures such as matting, mulching, etc. If the site cannot be adequately stabilized prior to October 1, temporary measures must be installed to divert storm flows around the Retention/Irrigation facility until adequate vegetation and stabilization occurs.

During Construction

If active construction is being conducted upstream of the Retention/Irrigation facility, all construction activity BMPs must remain in place to prevent high sediment loads into the Retention/Irrigation facility. If necessary additional BMPs must be installed to protect the Retention/Irrigation facility during construction.

Post Construction

After all construction activities are complete, necessary temporary BMPs to protect the integrity of the Retention/Irrigation facility shall be installed, if necessary, until:

- the drainage area for the Retention/Irrigation facility is adequately stabilized;
- vegetation in the irrigation area is adequately established; and
- the vegetated buffer strips maintenance plan is fully implemented.

.Maintenance Requirements

The following maintenance requirements apply to retention/irrigation systems:

Maintenance Agreement

Treatment controls are to be maintained by the owner/operator. Maintenance agreements between the owner/operator of the retention/irrigation system and the City may be required (See Appendix C for example maintenance agreement).

Maintenance Plan

A post-construction Maintenance Plan shall be prepared and made available at the City's request. The Maintenance Plan should address at least the following items (see Appendix D for more detailed suggested Maintenance Plan content and format):

- Operation plan and schedule, including site map;

- Maintenance and cleaning activities and schedule;
- Equipment and resource requirements necessary to operate and maintain facility; and
- Responsible party for operation and maintenance activities.

Maintenance Activities

The following activities are recommended to properly maintain Retention/Irrigation systems:

- Prevention of mosquito access to standing water sources, particularly below ground, is the best prevention plan, but can prove challenging due to multiple entrances and the need to maintain the hydraulic integrity of the system.
- Open storage designs such as ponds and basins will require routine preventive maintenance plans and may also require routine inspections and treatments by local mosquito and vector control agencies.

Alternative and Proprietary Control Measures

This Plan provides guidance for the selection and design of some of the more common on-site stormwater treatment control measures for new development. The standard treatment control measures (T-1 through T-12) included in this Section are non-proprietary designs that have been reviewed and evaluated by the City and determined to be generally acceptable. Because the performance of these measures has already been demonstrated and reviewed by the City, the plan check review and approval process will be routine for development projects that have selected one of the control measures from this Plan.

The City recognizes, however, that these pre-accepted treatment control measures may not be appropriate for all projects due to physical site constraints. Thus, the City will consider the use of alternative or proprietary control measures under any of the follow conditions:

1. If design guidelines for standard treatment control measures cannot be met due to physical site constraints, the City retains the discretion of using a lesser performance or design standard prior to accepting proprietary devices. For example: a vegetated swale with 1.5 feet/sec velocity would be considered preferable to installation of a proprietary fabric filter.
2. Alternative or proprietary treatment control devices will only be considered for approval after standard treatment control measures in the Plan have been rejected by the City.
3. If, for a specific development, the average cost of installation and operation of standard treatment controls is substantially greater than the average costs for similar installations, alternative or proprietary treatment technologies may be considered for approval.
4. Alternative or proprietary treatment technologies may be approved for redevelopment projects where existing site constraints preclude installation of standard treatment controls.

Alternative control measures may include landscape-type features or proprietary devices. Site designers should contact the City stormwater staff early on in the planning process in order to adequately demonstrate that the level and reliability of treatment provided by an alternative control measure is equivalent to that of the pre-accepted designs. The City shall review the design and construction method of the proposed technology to determine if the device is suitable for the specific land use and pollutant to be removed.

In general, any alternative measure must be designed to treat the SQDV or the SQDF. Procedures to calculate the SQDV and SQDF are provided in the Calculation Fact Sheets. Site runoff in excess of the SQDV and SQDF may be diverted around or through the treatment device. In addition, the project applicant must demonstrate that the pollutant removal of the proposed alternative control measure will be comparable to the pre-accepted control measures. Reliable performance data and sound engineering principles must be provided to demonstrate effective reliable treatment. Any proposed alternative must include all maintenance, operation, and construction requirements.

There are numerous manufactured proprietary devices available on the market. When proprietary control measures have been determined by the City to be pre-accepted, an Appendix may be added to this Plan and updated periodically to provide a list and description of acceptable proprietary devices.

The City encourages the development of innovative stormwater control measures and may consider a limited number of promising alternative control measures, including proprietary devices, on a ‘pilot basis’. In order for a pilot project to be considered for proprietary devices, the manufacturer and/or property owner must commit to participate and fund a monitoring program to verify the device’s performance. Site designers should anticipate additional review time and contact the City stormwater staff early in the process to request consideration of pilot installation projects.

GLOSSARY OF TERMS

100,000-Square Feet (SF) Commercial Development: Any commercial development that creates 100,000 SF or more of impermeable area, including parking areas.

303(d) Listed: Water bodies listed as impaired as per Section 303(d) of the 1972 Clean Water Act.

Automotive Repair Shop: A facility that is categorized in any one of the following SIC codes: 5013, 5014, 5541, 7532-7534, or 7536-7539.

Backfill: Earth or engineered material used to refill a trench or an excavation.

Berm: An earthen mound used to direct the flow of runoff around or through a structure.

Best Management Practice (BMP): Any program, technology, process, siting criteria, operational methods or measures, or engineered systems, which when implemented prevent, control, remove, or reduce pollution.

Best Management Practices (BMPs): Includes schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent, eliminate, or reduce the pollution of waters of the receiving waters. BMPs also include treatment requirements, operating procedures, and practices to control plant site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage.

Buffer Strip or Zone: Strip of erosion-resistant vegetation over which stormwater runoff is directed.

Catch Basin (also known as Inlet or Drain Inlet): Box-like underground concrete structure with openings in curbs and gutters designed to collect runoff from streets and pavements.

Clean Water Act (CWA): (33 U.S.C. 1251 et seq.) requirement of the NPDES program are defined under Sections 307, 402, 318 and 405 of the CWA.

Commercial Development: Any development on private land that is not heavy industrial or residential. The category includes, but is not limited to: hospitals, laboratories and other medical facilities, educational institutions, recreational facilities, plant nurseries, multi-apartment buildings, car wash facilities, mini-malls and other business complexes, shopping malls, hotels, office buildings, public warehouses and other light industrial complexes.

Conduit: Any channel or pipe for directing the flow of water.

Construction Activity: Includes clearing, grading, excavation, and contractor activities that result in soil disturbance.

Construction General Permit: An NPDES permit issued by the SWRCB for the discharge of stormwater associated with construction activity from soil disturbance of five (5) acres or more.

Threshold lowered to one acre beginning October 10, 2003 (Construction General Permit No. CAS000002).

Conveyance System: Any channel or pipe for collecting and directing the stormwater.

Culvert: A covered channel or a large diameter pipe that crosses under a road, sidewalk, etc.

Dead-end Sump: A below surface collection chamber for small drainage areas that is not connected to the public storm drainage system. Accumulated water in the chamber must be pumped and disposed in accordance with all applicable laws.

Denuded: Land stripped of vegetation or land that has had its vegetation worn down due to the impacts from the elements or humans.

Designated Public Access Points: Any pedestrian, bicycle, equestrian, or vehicular point of access to jurisdictional channels in the area subject to permit requirements.

Detention: The temporary storage of stormwater runoff to allow treatment by sedimentation and metered discharge of runoff at reduced peak flow rates. The capture and subsequent release of stormwater runoff from the site at a slower rate than it is collected the difference being held in temporary storage.

Directly Adjacent: Situated within 200 feet of the contiguous zone required for the continued maintenance, function, and structural stability of an environmentally sensitive area.

Directly Connected Impervious Area (DCIA): The area covered by a building, impermeable pavement, and/or other impervious surfaces, which drains directly into the storm drain without first flowing across permeable land area (e.g. turf buffers, grass-lined channels).

Directly Discharging: Outflow from a drainage conveyance system that is composed entirely or predominantly of flows from the subject, property, development, subdivision, or industrial facility, and not commingled with the flows from adjacent lands.

Discharge: A release or flow of stormwater or other substance from a conveyance system or storage container. Broader – includes release to storm drains, etc.

Effluent Limits: Limitations on amounts of pollutants that may be contained in a discharge. Can be expressed in a number of ways including as a concentration, as a concentration over a time period (e.g., 30-day average must be less than 20 mg/L), or as a total mass per time unit, or as a narrative limit.

Erosion: The wearing away of land surface by wind or water. Erosion occurs naturally from weather or runoff but can be intensified by land-clearing practices relating to farming, residential or industrial development, road building, or timber cutting.

Excavation: The process of removing earth, stone, or other materials, usually by digging.

Facility: Is a collection of industrial processes discharging stormwater associated with industrial activity within the property boundary or operational unit.

Filter Fabric: Geotextile of relatively small mesh or pore size that is used to: (a) allow water to pass through while keeping sediment out (permeable); or (b) prevent both runoff and sediment from passing through (impermeable).

Grading: The cutting and/or filling of the land surface to a desired shape or elevation.

Hazardous Substance: (1) Any material that poses a threat to human health and/or the environment. Typical hazardous substances are toxic, corrosive, ignitable, explosive, or chemically reactive; (2) Any substance named by EPA to be reported if a designated quantity of the substance is spilled in the waters of the United States or if otherwise emitted into the environment.

Hazardous Waste: A waste or combination of wastes that, because of its quantity, concentration, or physical chemical, or infectious characteristics, may either cause or significantly contribute to an increase in mortality or an increase in serious irreversible illness; or pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed. Possesses at least one of four characteristics (ignitability, corrosivity, reactivity, or toxicity) or appears on special EPA or state lists. Regulated under the federal Resource Conservation and Recovery Act and the California Health and Safety Code.

Illicit Discharges: Any discharge to an MS4 that is not composed entirely of stormwater except discharges authorized by an NPDES permit (other than the NPDES permit for discharges from the municipal separate storm sewer) and discharges resulting from emergency fire fighting activities.

Industrial General Permit: An NPDES Permit (No. CAS000001) issued by the SWRCB for the discharge of Stormwater associated with industrial activity. Board Order 97-03-DWQ.

Infiltration: The downward entry of water into the surface of the soil.

Inlet: An entrance into a ditch, storm sewer, or other waterway.

Integrated Pest Management (IPM): An ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties. Pesticides are used only after monitoring indicates they are needed according to established guidelines, and treatments are made with the goal of removing only the target organism.

Material Storage Areas: On site locations where raw materials, products, final products, by-products, or waste materials are stored.

Municipal Separate Storm Sewer System (MS4): A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains): (i) designed or used for collecting or conveying stormwater; (ii) which is not a combined sewer; and (iii) which is not part of a POTW as defined at Title 40 of the CFR 122.2. A “Small MS4” is defined as an MS4 that is not a permitted MS4 under the Phase I regulations. This definition of a Small MS4 applies to MS4 operated within cities and counties as well as governmental facilities that have system of storm sewers.

New Development: Land disturbing activities; structural development, including construction or installation of a building or structure, creation of impervious surfaces; and land subdivision.

Non-Stormwater Discharge: Any discharge to municipal separate storm drain that is not composed entirely of stormwater. Discharges containing process wastewater, non-contact cooling water, or sanitary wastewater are non-stormwater discharges.

Nonpoint Source Pollution: Pollution that does not come from a point source. Nonpoint source pollution originates from aerial diffuse sources that are mostly related to land use.

Non-Structural Source Control Measure: Low technology, low cost activities, procedures or management practices designed to prevent pollutants associated with site functions and activities from being discharged with stormwater runoff. Examples include good housekeeping practices, employee training, standard operating practices, inventory control measures, etc.

Notice of Intent (NOI): A formal notice to SWRCB submitted by the owner/developer of an industrial or construction site that said owner seeks coverage under a General Permit for discharges associated with industrial and construction activities. The NOI provides information on the owner, location, type of project, and certifies that the owner will comply with the conditions of the construction General Permit.

Notice of Termination (NOT): Formal notice to the SWRCB submitted by owner/developer that a construction project is complete.

NPDES Permit: NPDES is an acronym for National Pollutant Discharge Elimination System. An authorization, license, or equivalent control document issued by EPA or an approved State agency to implement the requirements of the NPDES program. NPDES is the national program for administering and regulating Sections 307, 318, 402, and 405 of the Clean Water Act (CWA). In California, the SWRCB has issued a General Permit for stormwater discharges associated with industrial activities.

Outfall: The point where stormwater discharges from a pipe, channel, ditch, or other conveyance to a waterway. The end point where storm drains discharge water into a waterway.

Parking Lot: Land area or facility for the temporary parking or storage of motor vehicles used personally, for business or for commerce with an impervious surface area of 5,000 square feet or more, or with 25 or more parking spaces.

Permeability: A property of soil that enables water or air to move through it. Usually expressed in inches/hour or inches/day.

Point Source: Any discernible, confined, and discrete conveyance from which pollutants are or may be discharged. This term does not include return flows from irrigated agriculture or agricultural stormwater runoff.

Pollutant: A substance introduced into the environment that adversely affects the usefulness of a resource.

Pollution Prevention (P2): Practices and actions that reduce or eliminate the generation of pollutants.

Precipitation: Any form of rain or snow.

Pretreatment: Treatment of wastewater before it is discharged to a wastewater collection system.

Process Wastewater: Wastewater that has been used in one or more industrial processes.

Receiving Stream: (for purposes of this Manual only) any natural or man-made surface water body that receives and conveys stormwater runoff.

Reclamation or Recycling (water reclamation or recycling): Planned use of treated effluent that would otherwise be discharged without being put to direct use.

Redevelopment: Development that includes, but is not limited to the following: the expansion of a building footprint or addition or replacement of a structure; structural development including an increase in gross floor area and/or exterior construction or remodeling; replacement of impervious surface that is not part of a routine maintenance activity; land disturbing activities related with structural or impervious surfaces. Redevelopment that results in the creation or addition of 5,000 square feet or more of impervious surfaces is subject to the requirements for stormwater mitigation. If the creation or addition of impervious surfaces is fifty percent or more of the existing impervious surface area, then stormwater runoff from the entire area (existing and changes) must be considered for purposes of stormwater mitigation. If the creation or changed area is less than fifty percent of the existing impervious area, then stormwater runoff from only the changed area needs mitigation.

Restaurant: A stand-alone facility that sells prepared foods and drinks for consumption, including stationary lunch counters and refreshment stands selling prepared foods and drinks for immediate consumption (SIC code 5812), where the total impervious area for development is greater than 5,000 square feet.

Retail Gasoline Outlet: Any facility engaged in selling gasoline and lubricating oils.

Retention: The storage of stormwater to prevent it from leaving the development site; may be temporary or permanent.

Runoff: Water originating from rainfall, melted snow, and other sources (e.g., sprinkler irrigation) that flows over the land surface to drainage facilities, rivers, streams, springs, seeps, ponds, lakes, wetlands, and shallow groundwater.

Run-on: Stormwater surface flow or other surface flow which enters property or area other than that where it originated. Off site stormwater surface flow or other surface flow which enters the site.

Scour: The erosive and digging action in a watercourse caused by flowing water.

Secondary Containment: Structures, usually dikes or berms, surrounding tanks or other storage containers and designed to catch spilled material from the storage containers.

Sedimentation: The process of depositing soil particles, clays, sands, or other sediments that were picked up by runoff.

Sediments: Soil, sand, and minerals washed from land into water, usually after rain, that accumulate in reservoirs, rivers, and harbors, destroying aquatic animal habitat and clouding the water such that adequate sunlight might not reach aquatic plants. Farming, mining, and building activities without proper implementation of BMPs will expose sediment materials, allowing them to be washed off the land after rainfalls.

Significant Materials: Includes, but not limited to, raw materials; fuels; materials such as solvents, detergents, and plastic pellets; finished materials such as metallic products; raw materials used in food processing or production; hazardous substances designed under Section 101(14) of CERCLA; any chemical the facility is required to report pursuant of Section 313 of Title III of SARA; fertilizers; pesticides; and waste products such as ashes, slag, and sludge that have the potential to be released with stormwater discharges.

Significant Quantities: The volume, concentrations, or mass of a pollutant in stormwater discharge that can cause or threaten to cause pollution, contamination, or nuisance that adversely impact human health or the environment and cause or contribute to a violation of any applicable water quality standards for receiving water.

Source Control BMPs: Any schedules of activities, structural devices, prohibitions of practices, maintenance procedures, managerial practices or operational practices that aim to prevent stormwater pollution by reducing the potential for contamination at the source of pollution.

Source Reduction (also Source Control): The technique of stopping and/or reducing pollutants at their point of generation so that they do not come into contact with stormwater.

Spill Guard: A device used to prevent spills of liquid materials from storage containers.

Spill Prevention Control and Countermeasures Plan (SPCC): Plan consisting of structures, such as curbing, and action plans to prevent and respond to spills of hazardous substances as defined in the CWA.

Storm Drains: Above- and below-ground structures for transporting stormwater to streams or outfalls for flood control purposes.

Storm Drain System: Network of above and below-ground structures for transporting stormwater to streams or outfalls.

Storm Event: A rainfall event that produces more than 0.1 inch of precipitation and is separated from the previous storm event by at least 72 hours of dry weather.

Stormwater: Stormwater runoff, snow-melt runoff, surface runoff, and drainage, excluding infiltration and irrigation tailwater. Urban runoff and snowmelt runoff consisting only of those discharges, which originate from precipitation events. Stormwater is that portion of precipitation that flows across a surface to the storm drain system or receiving waters.

Stormwater Discharge Associated with Industrial Activity: Discharge from any conveyance which is used for collecting and conveying stormwater which is related to manufacturing processing or raw materials storage areas at an industrial plant [see 40 CFR 122.26(b)(14)].

Stormwater Pollution Prevention Plan (SWPPP): A written plant that documents the series of phases and activities that, first, characterizes your site, and then prompts you to select and carry out actions which prevent the pollution of stormwater discharges.

Structural BMP or Control Measure: Any structural facility designed and constructed to mitigate the adverse impacts of stormwater and urban runoff pollution (e.g. canopy, structural enclosure). The category may include both Treatment Control BMPs and Source Control BMPs.

Treatment Control BMP (or Measure): Any engineered system designed to remove pollutants by simple gravity settling of particulate pollutants, filtration, biological uptake, media adsorption or any other physical, biological, or chemical process.

Treatment: The application of engineered systems that use physical, chemical, or biological processes to remove pollutants. Such processes include, but are not limited to, filtration, gravity settling, media adsorption, biodegradation, biological uptake, chemical oxidation and ultraviolet radiation.

Toxicity: Adverse responses of organisms to chemicals or physical agents ranging from mortality to physiological responses such as impaired reproduction or growth anomalies.

Turbidity: Describes the ability of light to pass through water. The cloudy appearance of water caused by suspended and colloidal matter (particles).

LIST OF ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
AC	Asphalt Concrete
ADL	Aerially Deposited Lead
AIMP	Impervious Area
AINF	Infiltration Area
ANSI	American National Standards Institute
APHA	American Public Health Association
APWA	American Public Works Association
ARS	Agricultural Research Service
AQMD	Air Quality Management District
ASTM	American Society for Testing Materials
AWWA	American Water Works Association
BAT	Best Available Technology (economically available)
BCT	Best Conventional Technology (pollution control)
BFP	Bonded Fiber Matrix
BMPs	Best Management Practices
BOD	Biochemical Oxygen Demand
CA	Contractor Activities
CAL-EPA	California Environmental Protection Agency
CAL-OSHA	California Division of Occupational Safety and Health Administration
CASQA	California Stormwater Quality Association
CCR	California Code of Regulations
CCS	Cellular Confinement System
CEQA	California Environmental Quality Act
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CFR	Code of Federal Regulations
CMA	Congestion Management Program
COE	U.S. Army Corps of Engineers
CPI	Coalescing Plate Interceptor
CWA	Clean Water Act (Federal Water Pollution Control Act of 1972 as amended in 1987)
DCIA	Directly Connected Impervious Area
DTSC	California Department of Toxic Substances Control

EEC	Effect Effluent Concentration
EIR	Environmental Impact Report
EMC	Event Mean Concentration
EOS	Equivalent Opening Size
ESA	Environmentally Sensitive Area
ESC	Erosion and Sediment Control
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
GIS	Geographical Information System
Hazmat	Hazardous Material
HSG	Hydrologic Soil Groups
IPM	Integrated Pest Management
JURMP	Jurisdictional Urban Runoff Management Program
MEP	Maximum Extent Practicable
MS4	Municipal Separate Storm Sewer System
MSDS	Material Safety Data Sheet
MSHA	Mine Safety and Health Administration
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NRC	National Response Center
NRCS	Natural Resources Conservation Service
NSF	National Science Foundation
NURP	National Urban Runoff Program
O&G	Oil and Grease
O&M	Operations and Maintenance
OSDS	On-site Disposal System
OSHA	Occupational Safety and Health Administration
P2	Pollution Prevention
PAHs	Polyaromatic Hydrocarbons
PAM	Polychlorinated Biphenyls
PCC	Portland Concrete Cement
PPT	Pollution Prevention Team
POTW	Publicly Owned Treatment Works

PSD	Particle Size Distribution
RCRA	Resource Conservation and Recovery Act
RWQCB	Regional Water Quality Control Board
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act
SIC	Standard Industrial Classification
SPCC	Spill Prevention Control and Countermeasure
SQDF	Stormwater Quality Design Flow
SQDV	Stormwater Quality Design Volume
SUSMP	Standard Urban Stormwater Mitigation Plan
SWMP	Stormwater Management Plan
SWPCP	Stormwater Pollution Control Plan
SWPPP	Stormwater Pollution Prevention Plan
SWRCB	State Water Resources Control Board
TMDL	Total Maximum Daily Load
TOC	Total Organic Carbon
TSS	Total Suspended Solids
UFC	Uniform Fire Code
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USDOT	United States Department of Transportation
USEPA	United States Environmental Protection Agency
WEF	Water Environment Federation

Standard Calculations for Diversion Structure Design

Introduction

Storm water runoff in excess of the water quality flow or volume is to be diverted around or through the treatment control measure. The following paragraphs provide equations and design criteria necessary to design diversion structures to divert runoff in excess of the SQDV or SDQF around or through the treatment control measures.

Diversion Structure Design

Capture or isolation of the SQDV is typically achieved by employing one of the following techniques:

- Divert the SQDV into the treatment control measure from the on-site storm drain system using weirs or orifices at or upstream of the point of entrance to the treatment control measure.
- Bypassing flows in excess of the SQDV within the treatment control measure using weirs and pipes for channel or pipe storm drain systems or routing excessive flows through a vegetated swale.

By employing diversion techniques, the water quality flow or volume is treated and discharged to the storm drain system and runoff that exceeds the water quality flow or volume is diverted or bypassed, untreated, directly to the downstream storm drain system.

Equations and criteria to design a diversion structure are provided below. Alternative designs may be considered subject to approval.

All diversion structures are designed using the on-site storm design event. The drainage design storm is established by the governing agency and is not the same as the stormwater quality design flow or volume. The drainage design storm is used to design the conveyance system, i.e. pipes, swales, etc. of the site without regard for treatment. The design engineer must ensure sufficient head room in the on-site system above the diversion to accommodate overflows.

Diverting Flows at the Inlet or Upstream of the Treatment Control Device

Diverting flow at the inlet to the treatment control is the more common approach to divert excess runoff. Figure B-1 illustrates the more commonly used diversion structures. The height of the weir to divert the flow is determined a follows:

<u>Treatment Control Measures Designed Based on the SQDV</u>

1. Determine the SQDV (see Section 5)
2. Utilizing design techniques provided in the treatment control measure fact sheets, determine the maximum height of the water level in the treatment control measure when the entire SQDV is being held,
3. Set the height of the diversion weir to the maximum height of the water level.
4. Determine weir dimensions needed to divert peak flows of the drainage design storm

using the following equation for a rectangular sharp-crested weir

$$Q_d = C \times L \times h^{1.5} \qquad \textit{eqn B-1}$$

Where: Q_d = Peak flow rate for drainage design storm, cfs

L = Effective length of weir, ft

C = Weir discharge coefficient

h = Depth of the flow above the crest of the weir, ft

The discharge coefficient "C" accounts for many factors, such as velocity of approach, in the weir equation. The height of the weir (H) and the height of the flow over the weir (h) are two characteristics of the sharp-crested weir that affect the value of C. Table B-1 can be used to approximate C for rectangular sharp-crested weirs without end contractions.

5. Provide sufficient head room in the treatment control to accommodate depth of flow over the weir.

Table B-1. Weir Discharge Coefficient (C) for Rectangular Sharp-crested Weirs Without End Contractions[1]

H/h	Head (h) over weir, ft						
	0.2	**0.4**	**0.6**	**0.8**	**1.0**	**2.0**	**5.0**
0.5	4.18	4.13	4.12	4.11	4.11	4.10	4.10
1.0	3.75	3.71	3.69	3.68	3.68	3.67	3.67
2.0	3.53	3.49	3.48	3.47	3.46	3.46	3.45
10.0	3.36	3.32	3.30	3.30	3.29	3.29	3.28
∞	3.32	3.28	3.26	3.26	3.25	3.25	3.24

1. From Lindsay and Franzini , (1979)

<u>Treatment Control Measures Designed Based on the SQDF</u>

1. Establish the size of the on-site drainage system (pipe diameter or dimensions) based on the drainage design storm
2. Determine the SQDF (see Section 5)
3. Determine the depth of flow in the on-site drainage system when carrying the SQDF using Manning's equation (eqn B-2)

$$SQDF = \frac{1.49}{n} A R^{\frac{2}{3}} S^{\frac{1}{2}} \qquad \textit{eqn B-2}$$

Where: SQDF = Water Quality Flow, cfs

n = Manning's roughness coefficient

A = Cross sectional area of drainage pipe or channel, ft^2

R = Hydraulic radius, ft

S = Slope of pipe or channel, ft/ft

4. Using nomographs or computer programs, determine the depth of flow at SQDF. Set the weir height at this depth.
5. Using Equation B-1, establish weir dimensions. Provide sufficient head room in treatment control to accommodate flows over the weir.

Bypassing Excess Flows within the Treatment Control Measure

For certain site conditions, bypassing runoff in excess of the SQDV must be achieved in the treatment control measure. When this occurs, the control measure must be designed to ensure the bypass system can be accommodated in the unit, i.e. sufficient depth, width and length to accommodate pipes, length of weirs, etc. The following discusses design considerations for the different treatment control measures.

<u>Bypassing Flows through Infiltration and Sedimentation/Filtration Treatment Control Measures</u>

Weirs, orifices or pipes in treatment control measures are used to bypass runoff in excessive of the SQDV and SQDF. Design of these measures is similar to the approach described above under diverting flows at the inlet to the treatment control measure. Bypass for filtration devices occurs in the sedimentation chamber.

Weirs

Weirs are commonly used to bypass excess storm events. Determining the height of the weir is based on the maximum water elevation in a treatment control device when holding the entire SQDV. To design the weir, use the procedures established under Diversion Structures for Treatment Control Measures Designed Using the SQDV.

Orifices

Orifices can be considered in place of weirs or pipes. To avoid drawing floatables into the bypass, a hooded orifice (see Figure B-2) should be designed using the equation B-3:

$$Q_d = C \times A \times (2gh)^{0.5} \qquad \textit{eqn B-3}$$

Where:

Q_d = Peak flow rate for drainage design storm, cfs

C = Orifice discharge coefficient, (use 0.6)

A = Area of orifice, ft^2

h = Depth of the water above midpoint of orifice, ft

g = 32.2 ft/sec^2

Hoods should extend into one-third of the permanent pool depth or one-foot whichever is greater. Commercial catch basin traps can be used in lieu of a hood.

Determining the elevation of the orifice is based on determining the maximum water elevation in a treatment control device when holding the entire SQDV. Use the procedures established under Diversion Structures for Treatment Control Measures Designed Using the SQDV to establish the elevation of the mid-point of the orifice opening.

The size of the orifice is determined by using Equation B-3 for the orifice to bypass the peak flow of the on-site storm.

Ensure sufficient head room in the treatment unit to accommodate flows through orifice.

Pipes

Pipes can also be employed to bypass excess runoff. Determining the invert elevation of the bypass inlet is based on determining the maximum water elevation in a treatment control device when holding the entire SQDV. To do this, use the procedures established under Diversion Structures for Treatment Control Measures Designed Using the SQDV to design a diversion weir.

For filtration control measures, a hooded inlet using a 90° elbow should be considered at the inlet to the bypass pipe to prevent drawing floatables into the bypass (see Figure B-2). Hoods should extend into one-third of the permanent pool depth or one-foot whichever is greater. Commercial catch basin traps can be used in lieu of a hood.

For infiltration control measures (see Figure B-3) bypass pipes are perforated and wrapped with filter fabric to avoid drawing sediment and small particles into the bypass pipe. Hoods are not necessary for these overflow pipes.

Bypass pipes are sized using the Manning's equation (Equation B-4) and sized to pass the peak flow of the drainage design storm, and assume the bypass pipes are flowing full. With this assumption, the Manning's equation, Equation B-4, reduces to:

$$D = \left(\frac{2.159 Q_d n}{s^{\frac{1}{2}}} \right)^{\frac{3}{8}} \qquad \textit{eqn B-4}$$

Where:
- D = Diameter of pipe, ft
- Q_d = Peak flow rate for drainage design storm, cfs
- n = Manning's coefficient for pipe material
- s = Slope of pipe, ft/ft (0.5% minimum required)

Provide sufficient head room in the treatment control to accommodate flows.

<u>Routing Excess Runoff Through a Vegetated Swale</u>

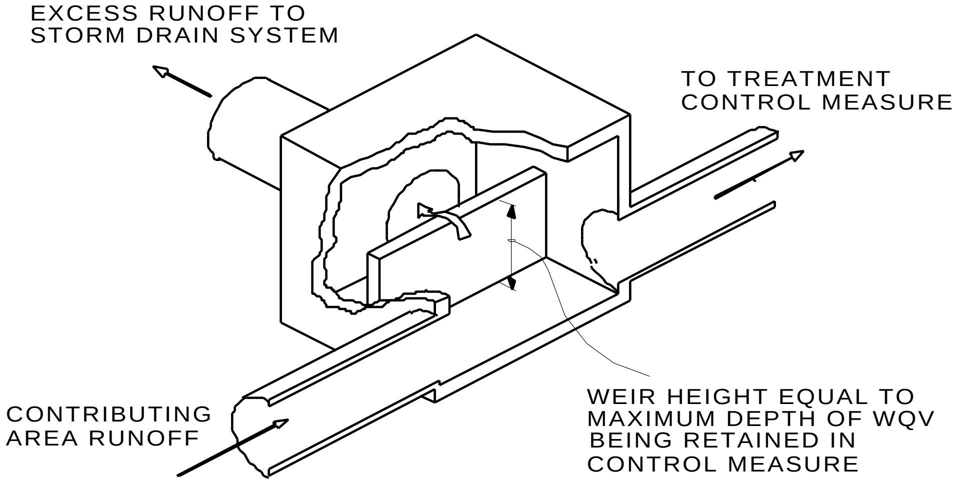
The depth of flow in a Vegetated Swale at SQDF is determined using a roughness coefficient of 0.2. If additional flows beyond the SQDF are to be directed to the vegetated swale, the roughness coefficient for these flows will be lower (approximately 0.03), because the flows exceeding the SQDF do not flow through the swale and are only influenced by surface friction/roughness. Swales with distinctly different roughness coefficients can be designed using an equivalent roughness coefficient that is determined based on the roughness associated with the wetted perimeters (P). For most on-site Vegetated Swale designs, there will be two different "n" values. An equivalent "n_e" value can be determined using equation B-5:

$$n_e^{\frac{3}{2}} = \frac{P_1 n_1^{\frac{3}{2}} + P_2 n_2^{\frac{3}{2}}}{P} \qquad \textit{eqn B-5}$$

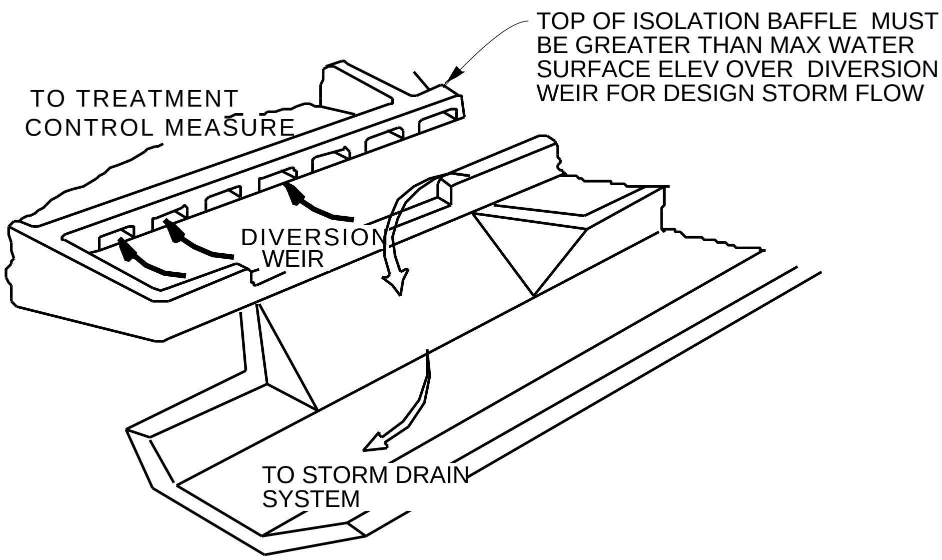
An iterative approach is used to develop an equivalent "n_e", that can be calculated with most computer hydraulic program applications:

1. Estimate an equivalent roughness coefficient (estimated "n_e");
2. Use the estimated roughness coefficient to determine the depth of flow using trial and error solution of Equation B-2 substituting the peak flow of the drainage design storm for the SQDF;
3. Use the calculated depth to determine the wetted perimeter for the drainage system;
4. Use the wetted perimeter associated with each "n" for the drainage system and using Equation B-5 to calculate the equivalent roughness coefficient (calculated "n_e"), and compare to the estimated "n_e"; and
5. Continue the process until the calculated "n_e" equals the estimated "n_e". This value is the equivalent roughness coefficient and used to design the Vegetated Swale according to recommendations provided in Fact Sheet T-2.

Note - This approach results in conservative n values. High flows in the swale may cause some vegetation to bend resulting in a lower n_1 and lower equivalent "n_e".



PIPE INTERCEPTOR ISOLATION/DIVERSION STRUCTURE



SURFACE CHANNEL DIVERSION STRUCTURE

Figure B-1. Common Diversion Structures at Inlets

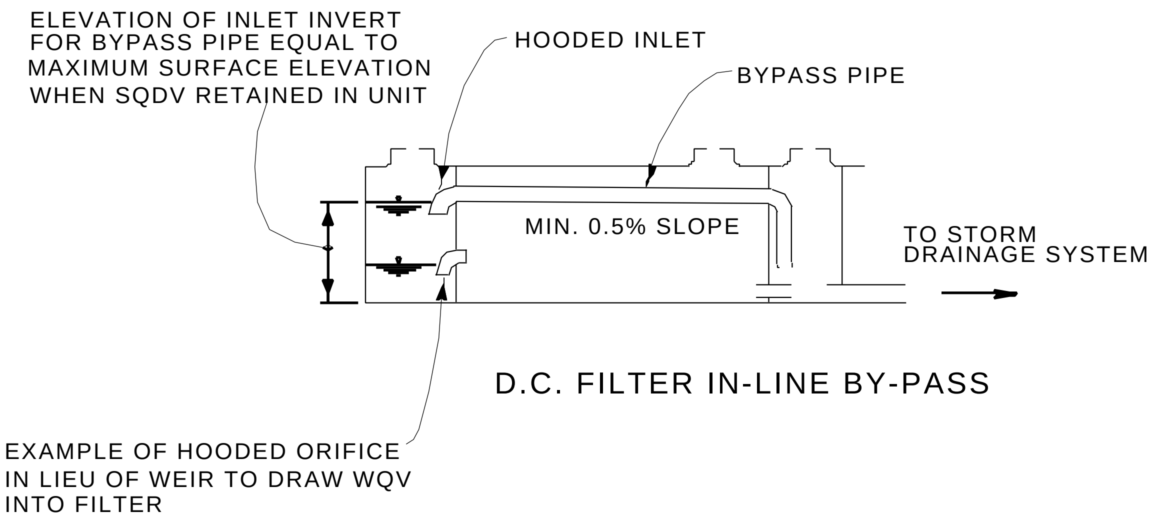


Figure B-2. Illustration of Pipe Bypass in a Filtration Device

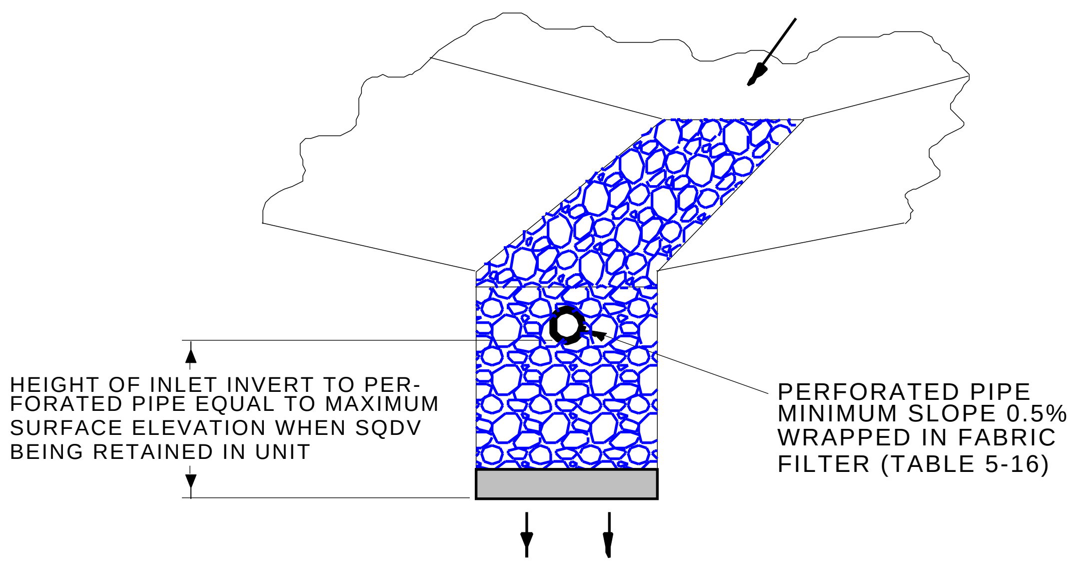


Figure B-3. Illustration of Pipe Bypass in Infiltration Trench

(Long Form)

Recorded at the request of:
City of Stockton

____
After recording, return to:
City of Stockton
City Clerk
____
____

Stormwater Treatment Device
Access and Maintenance
Agreement

OWNER: ____

PROPERTY ADDRESS:____

APN:____

THIS AGREEMENT is made and entered into in____________________, California, this___day of_____________, by and between_______________________________________, hereinafter referred to as "Owner" and the CITY OF STOCKTON, a municipal corporation, located in the County of San Joaquin, State of California hereinafter referred to as "CITY";

WHEREAS, the Owner owns real property ("Property") in the City of Stockton, County of San Joaquin, State of California, more specifically described in Exhibit "A" and depicted in Exhibit "B", each of which exhibits is attached hereto and incorporated herein by this reference;

WHEREAS, at the time of initial approval of development project known as___________ ______________________________________within the Property described herein, the City required the project to employ on-site control measures to minimize pollutants in urban runoff;

WHEREAS, the Owner has chosen to install a ___________________________________ ____, hereinafter referred to as "Device", as the on-site control measure to minimize pollutants in urban runoff;

WHEREAS, said Device has been installed in accordance with plans and specifications accepted by the City;

WHEREAS, said Device, with installation on private property and draining only private property, is a private facility with all maintenance or replacement, therefore, the sole responsibility of the Owner in accordance with the terms of this Agreement;

WHEREAS, the Owner is aware that periodic and continuous maintenance, including, but not necessarily limited to, filter material replacement and sediment removal, is required to assure peak performance of Device and that, furthermore, such maintenance activity will require compliance with all Local, State, or Federal laws and regulations, including those pertaining to confined space and waste disposal methods, in effect at the time such maintenance occurs;

NOW THEREFORE, it is mutually stipulated and agreed as follows:

1. Owner hereby provides the City or City's designee complete access, of any duration, to the Device and its immediate vicinity at any time, upon reasonable notice, or in the event of emergency, as determined by City's Director of Public Works no advance notice, for the purpose of inspection, sampling, testing of the Device, and in case of emergency, to undertake all necessary repairs or other preventative measures at owner's expense as provided in paragraph 3 below. City shall make every effort at all times to minimize or avoid interference with Owner's use of the Property.

2. Owner shall use its best efforts diligently to maintain the Device in a manner assuring peak performance at all times. All reasonable precautions shall be exercised by Owner and Owner's representative or contractor in the removal and extraction of material(s) from the Device and the ultimate disposal of the material(s) in a manner consistent with all relevant laws and regulations in effect at the time. As may be requested from time to time by the City, the Owner shall provide the City with documentation identifying the material(s) removed, the quantity, and disposal destination.

3. In the event Owner, or its successors or assigns, fails to accomplish the necessary maintenance contemplated by this Agreement, within five (5) days of being given written notice by the City, the City is hereby authorized to cause any maintenance necessary to be done and charge the entire cost and expense to the Owner or Owner's successors or assigns, including administrative costs, attorneys fees and interest thereon at the maximum rate authorized by the Civil Code from the date of the notice of expense until paid in full.

4. The City may require the owner to post security in form and for a time period satisfactory to the City of guarantee the performance of the obligations stated herein. Should the Owner fail to perform the obligations under the Agreement, the City may, in the case of a cash bond, act for the Owner using the proceeds from it, or in the case of a surety bond, require the sureties to perform the obligations of the Agreement. As an additional remedy, the Director may withdraw any previous stormwater related approval with respect to the property on which a

Device has been installed until such time as Owner repays to City its reasonable costs incurred in accordance with paragraph 3 above.

5. This agreement shall be recorded in the Office of the Recorder of San Joaquin County, California, at the expense of the Owner and shall constitute notice to all successors and assigns of the title to said Property of the obligation herein set forth, and also a lien in such amount as will fully reimburse the City, including interest as herein above set forth, subject to foreclosure in event of default in payment.

6. In event of legal action occasioned by any default or action of the Owner, or its successors or assigns, then the Owner and its successors or assigns agree(s) to pay all costs incurred by the City in enforcing the terms of this Agreement, including reasonable attorney's fees and costs, and that the same shall become a part of the lien against said Property.

7. It is the intent of the parties hereto that burdens and benefits herein undertaken shall constitute covenants that run with said Property and constitute a lien there against.

8. The obligations herein undertaken shall be binding upon the heirs, successors, executors, administrators and assigns of the parties hereto. The term "Owner" shall include not only the present Owner, but also its heirs, successors, executors, administrators, and assigns. Owner shall notify any successor to title of all or part of the Property about the existence of this Agreement. Owner shall provide such notice prior to such successor obtaining an interest in all or part of the Property. Owner shall provide a copy of such notice to the City at the same time such notice is provided to the successor.

9. Time is of the essence in the performance of this Agreement.

10. Any notice to a party required or called for in this Agreement shall be served in person, or by deposit in the U.S. Mail, first class postage prepaid, to the address set forth below. Notice(s) shall be deemed effective upon receipt, or seventy-two (72) hours after deposit in the U.S. Mail, whichever is earlier. A party may change a notice address only by providing written notice thereof to the other party.

IF TO CITY:	IF TO OWNER:
________________________	__________________________________
________________________	__________________________________
________________________	__________________________________
________________________	__________________________________

IN WITNESS THEREOF, the parties hereto have affixed their signatures as of the date first written above.

APPROVED AS TO FORM:

____
City Attorney

OWNER:

____
Name:______________________________
Title:______________________________

CITY OF STOCKTON:

____
Name:______________________________
Title:______________________________

OWNER:

____
Name:______________________________
Title:______________________________

ATTEST:

____
City Clerk Date

NOTARIES ON FOLLOWING PAGE

EXHIBIT A
(Legal Description)

EXHIBIT B
(Map/llustration)

(Short Form)

Recorded at the request of and mail to :

____

____

____

Covenant and Agreement Regarding
Stormwater Treatment Device Maintenance

The undersigned hereby certify that we are the owners of hereinafter legally described real property located in the City of Stockton County of San Joaquin, State of California.

Legal Description: ____

____

as recorded in Book _________________________, Page_______, Records of San Joaquin County,

which property is located and known as **(Address):** ___________________________________

____.

And in consideration of the City of Stockton allowing___________________________________

____

on said property, we do hereby covenant and agree to and with said City to maintain according to the Maintenance Plan (Attachment 1), all structural stormwater treatment devices including the following:

____

____.

This Covenant and Agreement shall run all of the above described land and shall be binding upon ourselves, and future owners, encumbrancers, their successors, heirs, or assignees and shall continue in effect until released by the authority of the City upon submittal of request, applicable fees, and evidence that this Covenant and Agreement is no longer required by law.

NOTARIES ON FOLLOWING PAGE

Maintenance Plan Guidance

This appendix identifies the basic information that shall be included in a maintenance plan. Refer to Fact Sheets for individual control measures regarding device-specific maintenance requirements.

A. Site Map:

1. Provide a site map showing boundaries of the site, acreage and drainage patterns/contour lines. Show each discharge location from the site and any drainage flowing onto the site. Distinguish between soft and hard surfaces on the map.
2. Identify locations of existing and proposed storm drain facilities, private sanitary sewer systems and grade-breaks for purposes of pollution prevention.
3. With legend, show locations of expected sources of pollution generation (outdoor work and storage areas, heavy traffic areas, delivery areas, trash enclosures, fueling areas, industrial clarifiers, wash-racks, etc). Identify any areas having contaminated soil or where toxins are stored or have been stored/disposed of in the past.
4. With legend, indicate types and locations of stormwater control measures which will be built to permanently control stormwater pollution. Distinguish between pollution prevention, treatment, sewer diversion, and containment devices.

B. Baseline Descriptions:

1. List the property owners and persons responsible for operation and maintenance of the stormwater control measures on site. Include phone numbers and addresses.
2. Identify the intended method of providing financing for operation, inspection, routine maintenance and upkeep of stormwater control measures.
3. List all permanent stormwater control measures. Provide a brief description of stormwater control measures selected and if appropriate, facts sheets or additional information.
4. As appropriate for each stormwater control measure provide:
    a. A written description and check list of all maintenance and waste disposal activities that will be performed. Distinguish between the maintenance appropriate for a 2-year establishment period and expected long-term maintenance. For example, maintenance requirements for vegetation in a constructed wetland may be more intensive during the first few years until the vegetation is established. The post-establishment maintenance plan shall address maintenance needs (e.g. pruning, irrigation, weeding) for a larger, more stable system. Include maintenance performance procedures for facility components that require relatively unique maintenance knowledge, such as specific plant removal/replacement, landscape features, or constructed wetland maintenance. These procedures shall provide enough detail for a person unfamiliar with maintenance to perform the activity, or identify the specific skills or knowledge necessary to perform and document the maintenance.

b. A description of site inspection procedures and documentation system, including record-keeping and retention requirements.

c. An inspection and maintenance schedule, preferably in the form of a table or matrix, for each activity for all facility components. The schedule shall demonstrate how it will satisfy the specified level of performance, and how the maintenance/inspection activities relate to storm events and seasonal issues.

d. Identification of the equipment and materials required to perform the maintenance.

5. As appropriate, list all housekeeping procedures for prohibiting illicit discharges or potential illicit discharges to the storm drain. Identify housekeeping BMPs that reduce maintenance of treatment control measures.

C. Spill Plan:

1. Provide emergency notification procedures (phone and agency/persons to contact).
2. As appropriate for site, provide emergency containment and cleaning procedures.
3. Note downstream receiving water bodies or wetlands which may be affected by spills or chronic untreated discharges.
4. As appropriate, create an emergency sampling procedure for spills. (Emergency sampling can protect the property owner from erroneous liability for down-stream receiving area clean-ups).

D. Facility Changes:

1. Operational or facility changes which significantly affect the character or quantity of pollutants discharging into the stormwater control measures will require modifications to the Maintenance Plan and/or additional stormwater control measures.

E. Training:

1. Identify appropriate persons to be trained and assure proper training.
2. Training to include:
   a. Good housekeeping procedures defined in the plan.
   b. Proper maintenance of all pollution mitigation devices.
   c. Identification and cleanup procedures for spills and overflows.
   d. Large-scale spill or hazardous material response.
   e. Safety concerns when maintaining devices and cleaning spills.

F. Basic Inspection and Maintenance Activities:

1. Create and maintain on site, a log for inspector names, dates and stormwater control measure devices to be inspected and maintained. Provide a checklist for each inspection and maintenance category.
2. Perform annual testing of any mechanical or electrical devices prior to wet weather.

3. Report any significant changes in stormwater control measures to the site management. As appropriate, assure mechanical devices are working properly and/or landscaped BMP plantings are irrigated and nurtured to promote thick growth.
4. Note any significant maintenance requirements due to spills or unexpected discharges.
5. As appropriate, perform maintenance and replacement as scheduled and as needed in a timely manner to assure stormwater control measures are performing as designed and approved.
6. Assure *unauthorized* low-flow discharges from the property do not by-pass stormwater control measures.
7. Perform an annual assessment of each pollution generation operation and its associated stormwater control measures to determine if any part of the pollution reduction train can be improved.

G. Revisions to Pollution Mitigation Measures:

1. If future correction or modification of pass stormwater control measures or procedures is required, the owner shall obtain approval from the governing stormwater agency prior to commencing any work. Corrective measures or modifications shall not cause discharges to by-pass or otherwise impede existing stormwater control measures.

H. Monitoring & Reporting Program

1. The governing stormwater agency may require a Monitoring & Reporting Program to assure the stormwater control measures approved for the site are performing according to design.
2. If required by local agency, the Maintenance Plan shall include performance testing and reporting protocols.

Hydrologic Soil Groups

This appendix includes information on the Hydrologic Soil Groups in San Joaquin County to use in designing various stormwater control measures:

Relevance of Hydrologic Soil Groups Information

The hydrologic soil groups of a development area are pertinent to design of controls that involve infiltration and for identifying sites appropriate for detention basins. The predominant soil group will control the effectiveness of infiltration facilities or the suitability of an area for impounding water. Hydrologic soil group information should be used for preliminary siting studies only. Actual design should be based on in-situ soil investigations and testing by a qualified engineer or geologist.

Table C-1. Typical Infiltration Rates

Soil Type (Hydrologic Soil Group)	*Soil Type VCFCD*	*Infiltration Rate (in/hr)*
A	6,7	1.00 – 8.3
B	4,5	0.5 – 1.00
C	2,3	0.17 – 0.27
D	1	0.02 – 0.10
Infiltration rates shown represent the range covered by multiple sources, e.g. ASCE, BASMAA, etc.		

Hydrologic Soil Groups

The hydrologic soil groups are classified by the USDA Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service. There are four hydrologic soil groups: A, B, C and D. Soils may be classified by two groups. Soil groups A and B have the highest infiltration rates, unless the soils under consideration have been compacted during construction. Soil groups A and B are typically the best candidate soils for construction of infiltration facilities. Sites with soil groups C and D are usually more appropriate for detention basins.

Soils in group A have a low runoff potential and high infiltration rate, as the soils typically are sands and gravel. Soil group B includes soils with moderate infiltration rates when completely wetted. Group B soils are sandy loam soils with moderately fine to moderately coarse textures. Soils in group C have slow infiltration rates when thoroughly wetted and these soils typically are silty-loam soils with an impeding layer or soils with moderately fine to fine texture. Group D soils have a high runoff potential and very slow infiltration rate when thoroughly wetted. Group D soils include clay soils with high swelling potential, soils in a permanent high water table and shallow soils over nearly impervious material.

The hydrologic soil information presented here should be used as a general overview. For more specific information, consult the *San Joaquin County Soil Survey* (USDA, NRCS) or contact the NRCS at (530) 662-3986.

Plants Suitable for Vegetative Control Measures

Vegetation serves primarily to maintain soil porosity and prevent erosion. The effectiveness and aesthetic appeal of control measures are enhanced by selection of appropriate vegetative cover. Turf grass is preferred, and some other ground covers also may be appropriate. An important maintenance consideration in the selection of appropriate vegetation is whether irrigation is planned for the site. Consult with City stormwater staff regarding selection of appropriate vegetation.

Table F-1 provides a sample list of appropriate vegetative covers. Additional suggested vegetative species are listed in Table F-2. The tables are intended as guides in selecting vegetative covers. For specific species suitability and care information, refer to the sources listed for these tables. Contact the Natural Resources Conservation Service for additional information.

Table F-1. Sample List of Appropriate Vegetative Covers

Plant Name Common (Latin)	Appropriate Species	Maintenance and Usage Notes*
Bermuda Grass (Cynodon)	Santa Ana hybrid Common	Moderate maintenance. Dormant (brown) in winter. Heat tolerant. Erosion control, swales.
Fescue (Festuca)	Red fescue (F. rubra)	Low to moderate maintenance. Tolerates some shade and poor soil. Lawns, swales, erosion control.
	“Kentucky 31" Tall Fescue (F. elatior)	Low maintenance. Tolerate shade and compacted soils. Rapid germination. Lawns, swales, erosion control. Useful as overseed for Bermuda grass during dormant (winter) season.
Ryegrass (Lolium)	Perennial (L. perenne)	Moderate maintenance. Heat intolerant. Fast sprouting. Useful as overseed for Bermuda grass during dormant (winter) season. Swales.
	Annual (L. multiflorum)	Annual (may live several seasons in mild climate). Moderate maintenance. Heat intolerant. Fast growing. Useful as overseed for winter-dormant species. Swales.

*Generally, these species will require supplemental irrigation.
Sources: ASCE, MWCG, Sunset

Table F-2. Additional Suggested Vegetative Covers

Plant Name Common (Latin)	Appropriate Species	Usage Notes
Kentucky Bluegrass	(Poa pratensis)	Irrigated Sites
Orchard grass (Dactylis)	“Akaroa” or “Berber” (D. glomerata)	Irrigated and Non-irrigated Sites
Wheatgrass (Agropyron)	“Luna” or “Topar” pubescent (A. intermedium trichophorum)	Irrigated and Non-irrigated Sites
Zorro Fescue (Vulpia)	(V. myuros)	Irrigated and Non-irrigated Sites
Creeping wild Rye (Leymus)	(L. triticoides)	Nonirrigated Sites
Brome (Bromus)	Blando (B. mollis)	Nonirrigated Sites
	California or “Cucamonga” (B. carinatus)	Nonirrigated Sites

Sources: ***NRCS-FOTG***

Manual of Standards for Erosion and Sediment Control Measures, Association of Bay Area Governments, 1995

Design Forms

Design Procedure Form for G-4.1: Turf Buffer

Designer:________________________________

Company:________________________________

Date:________________________________

Project:________________________________

Location:________________________________

1. Design Flow	$Q_{P, SQDF}$ = ____________ cfs
2. Design Width W_{TB} = (SQDF)/0.05 cfs/ft	W_{TB} = ____________ ft
3. Design Length (8 ft min.)	L_{TB} = ____________ ft
4. Design Slope (4% max.)	L_{TB} = ____________ %
5. Flow Distribution (Check type used or describe "Other")	_____ Slotted curbing _____ Modular Block Porous Pavement _____ Level Spreader _____ Other ____________________ ____________________
6. Vegetation (describe)	_____ ____________________
7. Outflow Collection (Check type used or describe "Other")	_____ Grass-lined Channel / Swale _____ Street Gutter _____ Storm Drain _____ Underdrain Used _____ Other ____________________ ____________________

Notes ____

____

____

____

____

____

Design Procedure Form for G-4.2: Grass–lined Channel

Designer:______________________________

Company:______________________________

Date:______________________________

Project:______________________________

Location:______________________________

1. Design Flow	$Q_{P,\ SQDF}$ = ____________ cfs
2. Channel Geometry	
A. Channel Bottom Width (b)	b = ____________ ft
B. Side slope (Z)	Z = ____________
3. Depth of flow at SQDF (d) (2 ft max., Manning n= 0.05)	d = ____________ ft
4. Design Slope	
A. s = 2 % max.	s = ____________ %
B. No. of grade controls required	____________ (number)
6. Vegetation (describe)	____________
7. Outflow Collection (Check type used or describe "Other")	_____ Grated Inlet _____ Infiltration Trench _____ Other ____________

Notes ______________________________

Design Procedure Form for T-1: Vegetated Buffer Strip

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Design Flow	$Q_{P, SQDF}$ = ________________ cfs
2. Design Width W_{VBS} = (SQDF)/0.005 cfs/ft	 W_{VBS} = ________________ ft
3. Design Length (15 ft min.)	L_{VBS} = ________________ ft
4. Design Slope (4% max.)	S_{VBS} = ________________ %
5. Flow Distribution (Check type used or describe “Other”)	_____ Slotted curbing _____ Modular Block Porous Pavement _____ Level Spreader _____ Other ________________________ ________________________________
6. Vegetation (describe)	_____ ________________________________
7. Outflow Collection (Check type used or describe “Other”)	_____ Grass Channel / Swale _____ Street Gutter _____ Storm Drain _____ Underdrain Used _____ Other ________________________ ________________________________

Notes ____

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Design Procedure Form for T-2: Vegetated Swale

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Design Flow	$Q_{P,\ SQDF}$ = ______________ cfs
2. Swale Geometry a. Swale Bottom Width (b) b. Side slope (Z)	b = ______________ ft Z = ______________
3. Depth of flow at SQDF (d) (2 ft max., Manning n= 0.20)	d = ______________ in
4. Design Slope a. s = 2% max. b. No. of grade controls required	s = ______________ % ______________ (number)
5. Design flow velocity (Manning n= 0.20)	V = ______________ft/sec
6. Design Length Minimum L = (10 min) × (flow velocity, ft/sec) × 60, or 100 ft	L = ______________ft
6. Vegetation (describe)	_____ ____________________________
7. Outflow Collection (Check type used or describe “Other”)	_____ Grated Inlet _____ Infiltration Trench _____ Underdrain Used _____ Other ______________________ ____________________________

Notes ____

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Design Procedure Form for T-3: Extended Detention Basin (Page 1 of 2)

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	________	%
b. Effective Imperviousness (Determine using Figure 3-4)	I_{wq} =	________	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40-hr drawdown and I_{wq}	V_u=	________	ac-ft
d. Watershed Area Tributary to EDB	Area =	________	ac
e. Calculate SQDV SQDV = (V_u/12) × Area	SQDV =	________	ac-ft
f. Calculate Design Volume Design Volume = SQDV × 1.2	Design Volume =	________	ac-ft
2. Outlet Works			
a. Outlet Type (check one)	Single Orifice	________	
	Multi-orifice Plate	________	
	Perforated Pipe	________	
	Other	________	
b. Depth of water above bottom orifice	Depth =	________	ft
c. Single Orifice Outlet			
1) Total Area	A =	________	in^2
2) Diameter or W × L	D =	________	in
d. Multiple Orifice Outlet			
1) Area per row of perforations	A =	________	in^2
2) Perforation Diameter (2 in max.)	D =	________	
3) No. of Perforations (columns) per Row	Perforations =	________	
4) No. of Rows (4-in spacing)	Rows =	________	
5) Total Orifice Area (Area per row) × (Number of Rows)	Area =	________	in^2

Design Procedure Form for T-3: Extended Detention Basin (Page 2 of 2)

Project:____

3. Trash Rack or Gravel Pack (check one)	Trash Rack_____ Gravel Pack_____
4. Basin Length-Width Ratio (2:1 minimum)	Ratio = ____________ L:W
5. Two-Stage Design	
a. Upper Stage	
1) Depth (2 ft min.)	Depth = _________ ft
2) Width (30 ft min.)	Width = _________ ft
3) Bottom Slope (2% to low flow channel)	Slope = _________ %
b. Bottom Stage	
1) Depth (1.5 to 3 ft deeper than Upper)	Depth = _________ ft
2) Storage Volume (5-15% of SQDV min.)	Volume = _________ ac-ft
6. Forebay Design	
a. Forebay Volume (5-10% of SQDV min.)	Volume = __________ ac-ft
b. Outlet pipe drainage time (~45 min)	Drainage Time __________ min
7. Low Flow Channel	
a. Depth (9-in min.)	Depth = ___________ ft
b. Flow Capacity (2 × outlet for Forebay)	Flow Capacity = ___________ gpm/cfm
8. Vegetation	Native Grasses __________
	Irrigated Turf __________
	Other ______________________________
9. Embankment	
a. Interior Slope (4:1 max.)	Interior Slope = __________ H/V
b. Exterior Slope (3:1 max.)	Exterior Slope = __________ H/V
10. Access	
a. Slope (10% max.)	Slope = _____________ %
b. Width (16 ft min.)	Width = _____________ ft

Notes

Design Procedure Form for T-4: Wet Pond (Page 1 of 3)

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	__________	%
b. Effective Imperviousness (Determine using Figure 3-4)	I_{wq} =	__________	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 12-hr drawdown and I_{wq}	V_u=	__________	ac-ft
d. Watershed Area Tributary to Wet Pond	Area =	__________	ac
Calculate SQDV = (V_u/12) × Area	SQDV =	__________	ac-ft
2. Permanent Pool			
a. Volume of Permanent Pool (1.0 – 1.5 times SQDV min.)	V_p =	__________	ac-ft
b. Depth			
1) Littoral Zone Depth (6 to 12 in)	Depth =	__________	ft
2) Deeper Zone Depth (4 to 8 ft average, 10 ft max.)	Average Depth =	__________	ft
	Max Depth =	__________	ft
c, Permanent Pool Surface Area			
1) Littoral Zone Area (25-40% Permanent Pool Surface)	Area =	__________	ac
	% of total	__________	%
2) Deeper Zone Area (60-40% Permanent Pool Surface)	Area =	__________	ac
	% of total	__________	%
3) Total Area	Total area =	__________	ac
3. Estimated Net Base Flow (must be > 0)			
$Q_{net} = Q_{inflow} - Q_{evap} - Q_{seepage} - Q_{evapotranspiration}$	Q_{inflow} =	__________	ac-ft
	Q_{evap} =	__________	ac-ft
	$Q_{seepage}$ =	__________	ac-ft
	$Q_{evapotranspiration}$	__________	ac-ft
	Q_{net} =	__________	ac-ft

Design Procedure Form for T-4: Wet Pond (Page 2 of 3)

Project:____

4. Outlet Works			
a. Outlet Type (check one)	Single Orifice	________	
	Multi-orifice Plate	________	
	Perforated Pipe	________	
	Other	________________	
b. Depth of water above bottom orifice	Depth =	________	ft
c. Single Orifice Outlet			
1) Diameter	D =	________	ft
2) Area	A =	________	ft^2
d. Multiple Orifice Outlet			
1) Area per row of perforations	A =	________	ft^2
2) Perforation Diameter (2-in max.)	D =	________	in
3) No. of Perforations (columns) per Row	Perforations =	________	
4) No. of Rows (4-in spacing)	Rows =	________	
5) Total Orifice Area (Area per row) _ (Number of Rows)	Area =	________	ft^2
5. Trash Rack or Gravel Pack Present?	Yes/No	________	
6. Basin Shape			
a. Length-Width Ratio	Ratio =	__________	L:W
7. Forebay Design			
a. Forebay Volume (5-10% of SQDV min.)	Volume =	________	ac-ft
b. Outlet pipe drainage time (< 45 min)	Drainage Time	________	min
8. Embankment Slope			
a. Interior Slope (4:1 max.)	Interior Slope =	________	L/W
b, Exterior Slope (3:1 max.)	Exterior Slope =	________	L/W

Design Procedure Form for T-4: Wet Pond (Page 3 of 3)

Project:____

9. Vegetation (Check type used or describe "Other")	_____ Native Grasses _____ Irrigated Turf Grass _____ Emergent Aquatic Plants (specify type/density) _____ Other ______________________ ______________________
10. Underdrains Provided?	Yes /No ___________

Notes:

Design Procedure Form for T-5: Constructed Wetland (Page 1 of 3)

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Determine Basin Storage Volume	
a. Percent Imperviousness of Tributary Area	I_a = ________ %
b. Effective Imperviousness (Determine using Figure 3-4)	I_{wq} = ________ %
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40-hr drawdown and I_{wq}	V_u= ________ in
d. Watershed Area Tributary to Constructed Wetland	Area = ________ ac
e. Calculate SQDV SQDV = (V_u/12) × Area	SQDV = ________ ac-ft
2. Wetland Pond Volume, Depth, and Water Surface Area	**<u>Minimums</u>**
a. Calculated Requirements, Minimum Permanent Pool: $Vol_{pool} \geq 0.75 \times SQDV$	Vol_{pool} > ________ ac-ft Water Area> ________ ac, estimated **<u>Actual Design</u>** Vol_{pool} = ________ ac-ft, actual Water Area = ________ ac, actual
b. Forebay Depth Range = 2.0–4.0 ft Volume Range = 5-10 % of SQDV	Depth = ________ ft Volume = ________ ac-ft,% =_______
c. Outlet Pool Depth Range = 2.0–4.0 ft Volume Range = 6-10% of SQDV	Depth = ________ ft Volume = ________ ac-ft,% =______

Continued on next page

Design Procedure Form for T-5: Constructed Wetland (Page 2 of 3)

Project:____

2. Wetland Pond Volume, Depth, and Water Surface Area (Continued)	
d. Free Water Surface Areas (Area = 30-50% combined) (Depth Range = 2.0–4.0 ft)	Depth = ________ ft Area = ________ ac, % = ____ Volume = ________ ac-ft
e. Wetland Zones with Emergent Vegetation (Depth Range = 6–12 in) (Area = 50-70%)	Depth = ________ ft Area = ________ ac, % = ____ Volume = ________ ac-ft
3. Estimated Net Base Flow (must be > 0) $Q_{net} = Q_{inflow} - Q_{evap} - Q_{seepage} - Q_{evapotranspiration}$	Q_{inflow} = ________ ac-ft Q_{evap} = ________ ac-ft $Q_{seepage}$ = ________ ac-ft $Q_{evapotranspiration}$ ________ ac-ft Q_{net} = ________ ac-ft
4. Outlet Works	
a. Outlet Type (check one)	Single Orifice ________ Multi-orifice Plate ________ Perforated Pipe ________ Other ________________
b. Depth of water above bottom orifice	Depth = ________ ft
c. Single Orifice Outlet	
1) Diameter	D = ________ ft
2) Area	A = ________ ft^2
d. Multiple Orifice Outlet	
1) Area per row of perforations	A = ________ in^2
2) Perforation Diameter (2-in max.)	D = ________
3) No. of Perforations (columns) per Row	Perforations = ________
4) No. of Rows (4-in spacing)	Rows = ________
5) Total Orifice Area (Area per row) _ (Number of Rows)	Area = ____________ in^2

Design Procedure Form for T-5: Constructed Wetland (Page 3 of 3)

Project:____

5. Trash Rack or Gravel Pack Present?	Yes/No ____________
6. Basin Shape a. Length-Width Ratio	 Ratio = ____________ L:W
8. Embankment Slope a. Interior Slope (4:1 max.) b, Exterior Slope (3:1 max.)	 Interior Slope = __________ L:W Exterior Slope = __________ L:W
9. Vegetation (Check type used or describe "Other")	_____ Native Grasses _____ Irrigated Turf Grass _____ Emergent Aquatic Plants (specify type / density)* _____ Other ___________________________________ *Describe Species Density and Mix: ________________ ____ ____ ____ ____

Notes:

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Design Procedure Form for T-6: Detention Basin/Sand Filter

Designer:______________________________

Company:______________________________

Date:______________________________

Project:______________________________

Location:______________________________

1. Determine Basin Storage Volume	
a. Percent Imperviousness of Tributary Area	I_a = ________ %
b. Effective Imperviousness (Determine using Figure 3-4)	I_{wq} = ________ %
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40-hr drawdown and I_{wq}	V_u= ________ ac-ft
d. Watershed Area Tributary to Detention Basin/Sand Filter	Area = ________ ac
e. Calculate SQDV SQDV = (V_u/12) × Area	SQDV = ________ ac-ft
2. Filter Surface Area (A_s)	
a. A_s (min) = Design Volume/(3 × 43,560 ft^2)	A_s (min) = ________ ft^2
b. Design A_s	A_s = ________ ft^2
3. Design basin depth, based on design filter area	
D = Design Volume/Design A_s	D = ________ ft
4. Filter Bed	
a) ASTM C33 Sand Layer (18-in min.)	________ in
b) ASSHTO M43-No.8 Gravel Layer (9-in min.)	________ in

Notes:

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Design Procedure Form for T-7: Porous Pavement Detention

Designer:____________________

Company:____________________

Date:____________________

Project:____________________

Location:____________________

1. Determine Basin Storage Volume	
a. Percent Imperviousness of Tributary Area	I_a = ________ %
b. Effective Imperviousness (Determine using Figure 3-4)	I_{wq} = ________ %
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 12-hr drawdown and I_{wq}	V_u= ________ ac-ft
d. Watershed Area Tributary to Porous Pavement Detention	Area = ________ ac
e. Calculate SQDV SQDV = (V_u/12) × Area	SQDV = ________ ac-ft
1. Basin Surface Area	
a. Design Volume (SQDV)	SQDV = ________ ft^3
b. A_s = Design Volume/(0.17 ft) (based on surcharge depth of 2 in)	A_s = ________ ft^2
2. Block Type	Block name: ________ Manufacturer: ________
a. Minimum open area = 40%	Open Area = ________ %
b. Minimum thickness = 4 in	Thickness ________ in
3. Base Course (Check)	
a. ASTM C33 Sand Layer (1-in)	Sand Layer ________
b. ASSHTO M43-No.8 Gravel Layer (9-in)	Gravel Layer ________

Notes:

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Design Procedure Form for T-8: Porous Landscape Detention

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	________	%
b. Effective Imperviousness (Determine using Figure 3-4)	I_{wq} =	________	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 12-hr drawdown and I_{wq}	V_u=	________	ac-ft
d. Watershed Area Tributary to Porous Landscape Detention	Area =	________	ac
e. Calculate SQDV SQDV = (V_u/12) × Area	SQDV =	________	ac-ft
2. Basin Surface Area			
a. Design Volume (SQDV)	SQDV =	________	ft^3
b. Average Depth	Average Depth =	________	ft
c. A_s = Design Volume / Average Depth	A_s =	________	ft^2
3. Base Course Layers (check)	Sandy Loam Turf	________	in (6-in min.)
	Sand/peat mix	________	in (18-in min.)
	Gravel	________	in (9-in min.)
4. Subsurface Drainage (check)	________	Infiltration to subgrade with permeable geotextile membrane	
	________	Underdrain with impermeable membrane	
	________	Underdrain with permeable goetextile membrane	

Notes:

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Design Procedure Form for T-9: Infiltration Basin

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Determine Basin Storage Volume	
a. Percent Imperviousness of Tributary Area	I_a = __________ %
b. Effective Imperviousness (Determine using Figure 3-4)	I_{wq} = __________ %
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40-hr drawdown and I_{wq}	V_u= __________ ac-ft
d. Watershed Area Tributary to Infiltration Basin	Area = __________ ac
e. Calculate SQDV SQDV = (V_u/12) × Area	SQDV = __________ ac-ft
2. Maximum Allowable Depth ($D_m = t \times I/12 \times s$)	
a. Site infiltration rate (I)	I = __________ in/hr
b. minimum drawdown time (t = 40 hrs)	t = __________ hrs
c. safety factor (s)	s = __________
d. $D_m = t \times I/12 \times s$	D_m = __________ ft
3. Basin Surface Area $A_m = (SQDV)/D_m$	A_m = __________ ft^2
4. Vegetation (Check type used or describe "Other")	____ Native Grasses ____ Irrigated Turf Grass ____ Other

Notes:

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Design Procedure Form for T-10: Infiltration Trench

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	__________	%
b. Effective Imperviousness (Determine using Figure 3-4)	I_{wq} =	__________	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40-hr drawdown and I_{wq}	V_u=	__________	ac-ft
d. Watershed Area Tributary to Infiltration Trench	Area =	__________	ac
e. Calculate SQDV SQDV = (V_u/12) × Area	SQDV =	__________	ac-ft
2. Trench Water Depth			
a. Soil infiltration rate	I =	__________	in/hr
b. Safety factor (S)	s =	__________	ft
c. Drawdown time (t = 40 hrs)	t =	__________	hrs
d. Max water depth (≤ 8 ft)			
$D_m = I \times t/12 \times s$	D_m =	__________	ft
3. Trench Bottom Surface Area			
$A_s = (SQDV)/D_m$	A_s =	__________	ft^2

Notes:

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Design Procedure Form for T-11.1: Austin Sand Filter (Page 1 of 2)

Designer:________________________________

Company:________________________________

Date:________________________________

Project:________________________________

Location:________________________________

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	__________	%
b. Effective Imperviousness (Determine using Figure 3-4)	I_{wq} =	__________	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40-hr drawdown and I_{wq}	V_u=	__________	in
d. Watershed Area Tributary to Media Filter	Area =	__________	ac
e. Calculate SQDV SQDV = (V_u/12) × Area	SQDV =	__________	ac-ft
2. Maximum Water Depth			
a. Storm drainage system invert elevation at proposed connection to storm drain	Inlet Elevation	__________	ft
b. Minimum control measure outlet invert elevation of sand filter at minimum grade:	Outlet Elevation	__________	ft
c, Estimate filter depth or use minimum depth of filter media and determine the difference in elevation between inverts of filter inlet and outlet:	Filter Depth	__________	ft
d. Site plan surface elevation at control measure location	Surface Elevation	__________	ft
e. Determine inlet invert elevation into sedimentation basin	Inlet Elevation (Sed. Basin)	__________	ft
f. Determine maximum allowable depth of water (2_h) in the sedimentation basin considering elevation differences between inlet and outlet invert elevations of sedimentation basin and filter and surface elevation. (This height will establish weir height or elevation of inlet invert for bypass pipes and orifices.)	Maximum Allowable Depth	__________	ft

Design Procedure Form for T-11.1: Austin Sand Filter (Page 2 of 2)

Project:____

3. Filter Surface Area		
a. Sand Bed Depth	d_f = ____________	ft
b. Coefficient of permeability for sand filter	k = ____________	ft/hr
c. One half of maximum allowable depth over filter (h).	h = ____________	ft
d. Time required for runoff to pass through filter.	t_f = ____________	hrs
e. Filter Surface Area (min.) $A_{fm} = \frac{(SQDV)(d_f)}{k(h+d_f)(t_f)}$	A_{fm} = ____________	ft^2
4. Filter Basin Volume		
Filter Basin Volume = 0.2 × (SQDV)	FBV = ____________	ft^3

Notes:

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Design Procedure Form for T-11.2:: DC Sand Filter (Page 1 of 2)

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	__________	%
b. Effective Imperviousness (Determine using Figure 3-4)	I_{wq} =	__________	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40-hr drawdown and I_{wq}	V_u=	__________	in
d. Watershed Area Tributary to Media Filter	Area =	__________	ac
e. Calculate SQDV SQDV = (V_u/12) × Area	SQDV =	__________	ac-ft

2. Minimum Filter Area			
$$A_{fm} = \frac{(SQDV)(d_f)}{k(h+d_f)(t_f)}$$			
a. SQDV	SQDV =	__________	ft^3
b. Sand bed depth (d_f)	d_f =	__________	ft
c. Filter Coefficient (k)	k =	__________	ft/hr
d. Draw-down time (t_f= 40 hr)	t =	__________	hr
e. one half maximum allowable water depth over filter (h)	h =	__________	ft
f. Minimum filter area	A_{fm} =	__________	ft^2

3. Select Filter Width, Compute Filter Length			
a. Select a Filter Width (W_f)	W_f =	__________	ft
b. Compute filter length $L_f = A_{fm}/W_f$	L_f =	__________	ft
c. Determine adjusted filter area (Round L_f to closest whole number) A_f = $W_f \times L_f$	A_f =	__________	ft^2
(From this point, the formula assume rectangular cross section of filter shell.)			

Design Procedure Form for T-11.2: DC Filter (Page 2 of 2)

Project:___________________________________

4. Compute the Storage Volume of Top of the Filter (V_{tf}) $V_{tf} = A_f \times (2h)$	V_{tf} = ____________ ft^3
5. Compute the Storage in the Filter Voids (Vv) (Assume 40% voids in the filter media) $V_v = A_f$ _ $(d_f + d_g) \times 0.40$	V_v = ____________ ft^3
6. Flow Through Filter During Filling (V_Q) (Assume 1-hour to fill) V_Q=k _ A_f _ $(d_f + d_g) \times t_f / d_f$ Use: k = 2 ft/day = 0.0833 ft/hr t_f = 1 hr to fill voids	V_Q = ____________ ft^3
7. Compute Net Volume to be Stored in Permanent Pool Awaiting Filtration (Vst) V_{st} = SQDV - V_{tf} – V_v - V_Q	V_{st} = ____________ ft^3
8. Compute Minimum Length of Permanent Pool (Lpm) $L_{pm} = V_{st} /(2h)(W_f)$	L_{pm} = ____________ ft
9. Compute Minimum Length of Sediment Chamber (L_s) (to contain 20% of SQDV) If V_{st} < (0.2_SQDV), use:L_s=0.2_SQDV /(2h)(W_f) If V_{st} > (0.2_SQDV), use:L_s=V_{st} /(2h)(W_f)	L_s = ____________ ft
10. Set Final Length of Permanent Pool (L_p) If $L_{pm} \geq (L_s + 2$ ft), use: $L_p = L_m$ If $L_{pm} < (L_s + 2$ ft), use: $L_p = (L_s + 2$ ft)	L_p = ____________ ft
11. Set Final Length of Clear Well (Lcw) L_{cw} = 3 ft min.	L_{cw} = ____________ ft

Notes:

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Design Procedure Form for T-11.3: Delaware Sand Filter

Designer:______________________________

Company:______________________________

Date:______________________________

Project:______________________________

Location:______________________________

1. Minimum Surface Areas of the Chambers	
If 2_h < 2.67 ft (2'-8")	
$A_{sm} = A_{fm} = (SQDV)/(4.1\_h + 0.9)$	
If 2_h > 2.67 ft (2'-8")	
$A_{sm} = A_{fm} = \frac{(SQDV)(d_f)}{k(h + d_f)t_f}$	
a. SQDV	SQDV = ________ ft^3
b. Sand bed depth (d_f)	d_f = ________ ft
c. Filter Coefficient (k)	k = ________ ft/hr
d. Draw-down time (t_r)	t = ________ hr
e. One half maximum allowable water depth over filter (h)	h = ________ ft
f. A_{sm} (Sediment Chamber Area) and A_{fm} (Filter Surface Area)	A_{sm} and A_{fm} = ________ ft^2
2. Sediment Chamber and Filter Width/Length	
a. Select width ($W_s = W_f$ = 18 – 30 in)	$W_s = W_f$ = ________ ft
b. Filter length ($L_s = L_f = A_{fm}/W_f$)	$L_s = L_f$ = ________ ft
c. Adjusted length (rounded)	$L_s = L_f$ = ________ ft
d. Adjusted area ($A_s = A_f = W_f \times L_f$)	$A_s = A_f$ = ________ ft^2
3. System Storage Volume	
a. Storage in filter voids ($V_v = A_f \times (d_f + d_f) \times 0.4$)	V_v = ________ ft
b. Flow through filter ($V_Q = k \times A_f (d_f + h)$ 1hr/d_f)	V_Q = ________ ft
c. Required net storage ($V_{st} = SQDV – V_v – V_Q$)	V_{st} = ________ ft
d. Available storage ($V_{sf} = 2h \times (A_f + A_s)$)	V_{sf} = ________ ft^2
If $V_{sf} \geq V_{st}$, sizing is complete	
If $V_{sf} < V_{st}$, repeat steps 2 and 3	

Design Procedure Form for T-13: Retention/Irrigation

Designer:____

Company:____

Date:____

Project:____

Location:____

1. Determine Basin Storage Volume			
a. Percent Imperviousness of Tributary Area	I_a =	________	%
b. Effective Imperviousness (Determine using Figure 3-4)	I_{wq} =	________	%
c. Required Unit Basin Storage Volume (V_u) Use Figure 5-1 with 40-hr drawdown and I_{wq}	V_u=	________	in
d. Watershed Area Tributary to Infiltration Trench	Area =	________	ac
e. Calculate SQDV	SQDV =	________	ac-ft
SQDV = (V_u/12) × Area	SQDV =	________	ft^3
2. Irrigation Area			
Infiltration rate (r)	r =	________	in/hr
A = (SQDV × 12)/(60 × r)	A =	________	ft^2
3. Vegetation (describe)	____ ________		

Notes:

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References

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